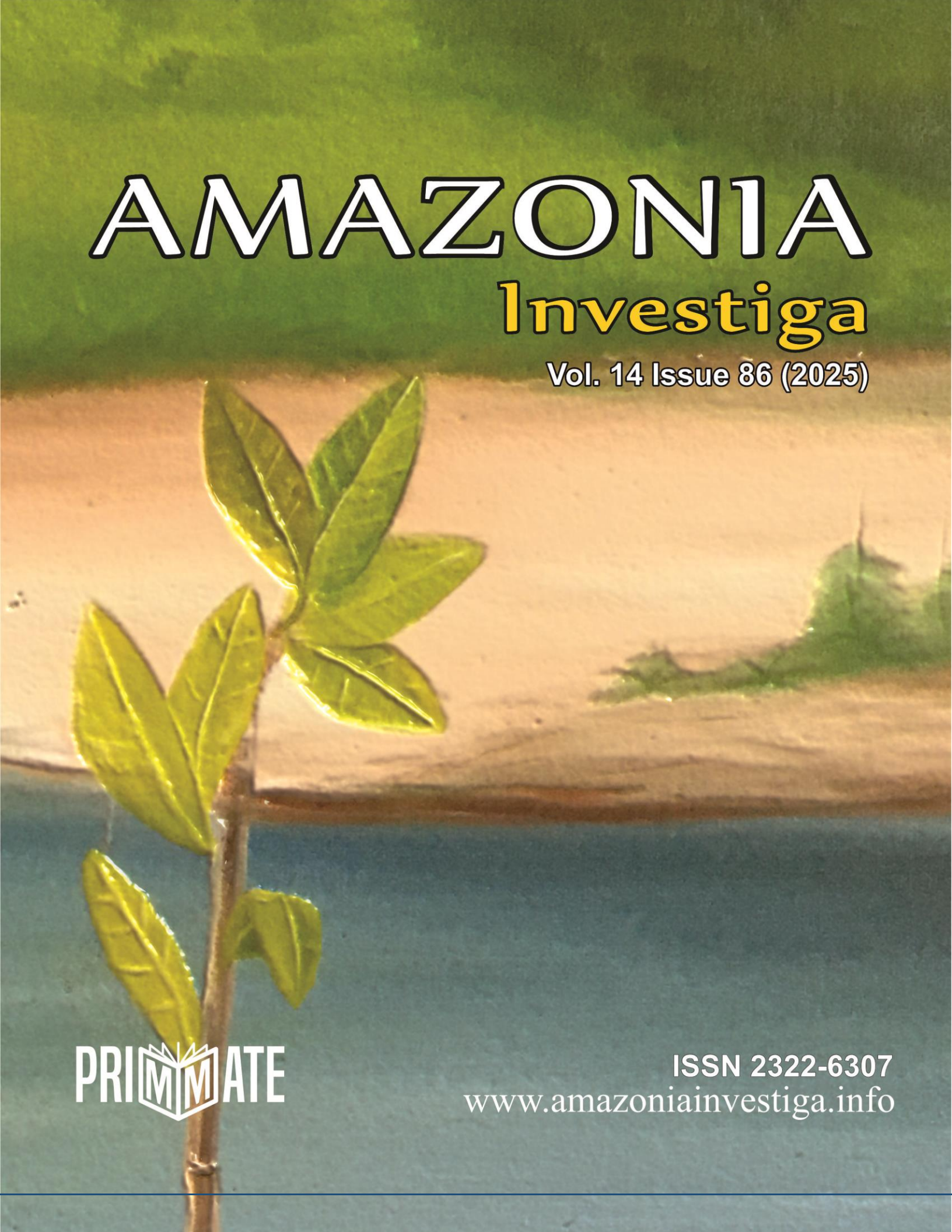

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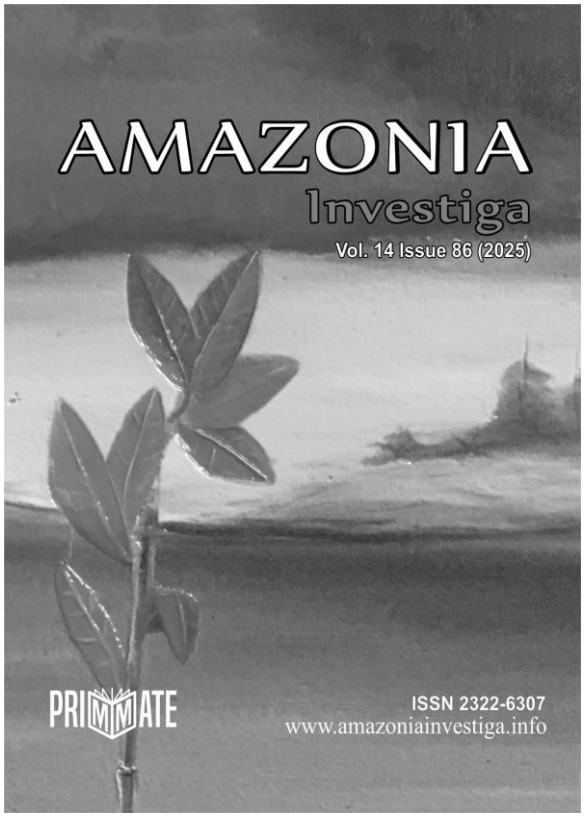

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Decoding the fiduciary duty of loyalty

РОЗШИФРОВУЮЧИ ФІДУЦІАРНИЙ ОБОВ'ЯЗОК ЛОЯЛЬНОСТІ

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Abstract

The article focuses on the duty of loyalty, which is fundamental to the fiduciary relationship as a legal concept. The inseparability of fiduciary relationship and the duty of loyalty is revealed through its attributive legal nature, which is related with the exercise of derivative powers delegated to the fiduciaries and appropriation of thereof results by the beneficiaries. The study identifies loyalty as a legal standard rather than a specific duty, emphasizing the need for clarity on what constitutes "acting in the best interests" of the company. It concludes that while fiduciary loyalty involves a framework of prohibitions to safeguard beneficiary interests, the intertwining of fiduciary duties of care and loyalty, by way of introduction the good faith duty in the corporate law, complicates the doctrinal consistency of the context of this term. Ultimately, the conclusions suggest a clearer definition of fiduciary loyalty in general terms and with the incorporation of the duty of good faith in the corporate law in particular.

Keywords: fiduciary duties, recodification of civil law, duty of loyalty, rule of prohibition of conflict of interests, rule of prohibition of unauthorised profits, fiduciary duty of good faith.

Анотація

Статтю присвячено обов'язку лояльності, який є основоположним для фідуціарних відносин як правової концепції. Нерозривність фідуціарних відносин та обов'язку лояльності розкривається через його атрибутивну правову природу, яка пов'язана зі здійсненням похідних повноважень, делегованих фідуціарам, та привласненням результатів їх діяльності бенефіціарами. Дослідження визначає лояльність як правовий стандарт, а не конкретний обов'язок, наголошуючи на необхідності чіткого визначення того, що означає «діяти в найкращих інтересах» компанії. У дослідженні зроблено висновок, що хоча фідуціарна лояльність передбачає систему заборон для захисту інтересів бенефіціарів, переплетення фідуціарних обов'язків турботи та лояльності, шляхом запровадження обов'язку добросовісності в корпоративному праві, ускладнює доктринальну узгодженість змісту цієї категорії. Зрештою, висновки пропонують більш чітке визначення фідуціарної лояльності в цілому та і з врахуванням обов'язку добросовісності в корпоративному праві зокрема.

Ключові слова: фідуціарні обов'язки, рекодифікація цивільного права, обов'язок лояльності, правило неконфліктності, правило заборони отримання несанкціонованого прибутку, фідуціарний обов'язок добросовісності.

Introduction

The doctrine of fiduciary legal relations is an extraordinary phenomenon for Ukrainian law: new and at the same time well-established. As in many countries of continental law, corporate law was the main factor in reception of this legal construction. For the first time the fiduciary obligations were set in the acts of the soft law, namely in the Principles of Corporate Governance (Decision No. 571, 2003), and afterwards in the Corporate Governance Code (Decision No. 118, 2020). In 2007, the National Bank of Ukraine approved Methodological Recommendations for Improving Corporate Governance in the banks of Ukraine

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(hereinafter – Methodological Recommendations), which also contained soft-law norms concerning fiduciary obligations (Resolution No. 98, 2007). However, in practical terms, introduction of the said norms had changed relatively nothing, as fiduciary principles were regarded more as good governance principles rather than an effective legal remedy, which might be applied by the court. The situation had changed in 2021, when the doctrine of fiduciary duties was implemented through the OECD Corporate Governance Principles (OECD, 2023), through references to it in the case law of the Supreme Court (Resolution in case No. 910/11027/18, 2021).

In 2024, a new stage of the development of the fiduciary duty doctrine has been reached, which is associated with the European integration processes, the ongoing recodification of the civil legislation of Ukraine, which "main goal […] is the further "Europeanization" of the code" (Tsiura et al., 2023, p. 306), and the approval of the Ukraine Facility plan by the European Parliament and the Council (European Union, 2024), which contains a plan for reforms, including in the area of corporate governance (The Cabinet of Ministers of Ukraine, 2024). Under the corporate governance term we understand the "complex of relationships between the management of the corporation, the board of directors, shareholders, and other stakeholders (stakeholders - trade unions, the state, consumers, etc.) to manage the activities of the corporation to achieve its strategic objectives" (Hurman, 2023, p. 252).

The expected result of the corporate governance reform (The Cabinet of Ministers of Ukraine, 2024) is creation of one (Management Board) or two levels (Management Board and Supervisory Board) of corporate governance bodies, mainly in the State-owned companies, all of which officers would be bound by fiduciary duties, including the duty of loyalty. Current Ukrainian legislation still doesn't provide a clear understanding either for corporate officers, attorneys or judges of what's within the context of fiduciary loyalty: if an obligation to avoid conflicts is quite clear, there is still a question how the member of the Management or Supervisory Board shall understand if it acts in company's best interests? Is it possible, for instance, to oblige the company's officials to act in its best interests? If there is a behavioral model for fulfilling the fiduciary loyalty's obligation?

The problem is also aggravated by the fact that Ukrainian court practice lacks precise interpretation of the fiduciary loyalty even on the level of Ukrainian Supreme Court (for instance, see Resolution in case No. 902/183/22, 2023; Resolution in case No. 910/7305/21, 2024): the point on duty to act in the best interests of the company is mentioning in number of cases, but Supreme Court still has not managed to elaborate the coherent concept of fiduciary duty of loyalty.

On the other hand, respective doctrinal approaches are also often confusing: Professor Andrew Gold raises the question of whether the concept of fiduciary loyalty can be formulated in general, on the opposite, Professor Matthew Conaglen narrows the scope of loyalty to the number of obligations and Professor Lionel Smith argues that the duty to act in company's best interests is not a legal duty at all. Moreover, the recent studies shows that fiduciary loyalty also contains the good faith obligation in corporate law, which in essence doesn't correspond to the classic civil understanding of the good faith.

Therefore, this article focuses on resolving the practical problem of interpreting the scope and content of the fiduciary loyalty, which becomes even more relevant as a corporate governance reform in Ukraine is ongoing and it would result in creation of corporate bodies in all State-owned companies, with numerous doctrinal approaches, each of them having its advantages and cons. The ultimate goal is to study and formulate approaches to the following points: a) if a fiduciary loyalty shall be regarded as civil obligation. In the other words, is it establishes the existence behavioral model, which company's officer might potentially be obliged to fulfill?; b) to disclose the main features of the duty of loyalty and assess if it should be regarded as the basis of fiduciary relations in general; c) to disclose the place of rule of prohibition of conflict of interests, rule of prohibition of unauthorized profits and other positive rules in the content of fiduciary loyalty; d) to reveal why good faith is regarded as the element of the fiduciary loyalty in corporate law and what is its content; e) to formulate the doctrinal approach of what it means to act in the company's best interest, both in general scope and specifically in the sphere of corporate law, which content is supplemented by number of limitations, set by the good faith duty.

Methodology

Research design. The study is based on a combination of quantitative and qualitative analysis of the doctrine of fiduciary duties in corporate law. The purpose of the study is to provide a detailed examination

of the duty of loyalty as an integral element of fiduciary duties, taking into account its evolution, legal nature and functions in the modern corporate law doctrine, as well as to provide approaches for practical usage by way disclosing the elements of fiduciary loyalty and showing their practical application in foreign jurisdictions.

Time frame. The study covers the legal provisions from 2003 to the present, and Ukrainian courts' practice since 2021, with a special focus on the period of corporate reforms in Ukraine in 2021-2024. The timeframe was determined to analyse the implementation of fiduciary duties in Ukrainian corporate law and the practice of its application.

Specific sources consulted. The main sources used in the course of the research are modern works of scholars, including the studies of Professors Matthew Conaglen, Lionel Smith, Robert Sitkoff, Tamar Frankel, Hillary Sale and others, relating to fiduciary duties, as well as Ukrainian legislation and court practice in this area.

Analysis process. The study was conducted with the usage of both general scientific and special methods of knowledge. Dogmatic method was used to disclose the content of the fiduciary norms and its interpretation. This analysis is based on a systematic review of legal acts, judicial practice, and scientific sources to reveal the essence and scope of legal duties, which establish the auxiliary and preventive mechanism to ensure the officer would act in company's best interests. The basic method of this study was the dialectical method, which was used to evaluate different approaches of scholars to the content and legal nature of the fiduciary duty of loyalty. There were also applied such special scientific methods as the methods of system analysis, which allowed to summarise the features of fiduciary duty of loyalty, the formal legal method was used to analyse case law, and the historical and legal method that made it possible to trace the evolution of the definition of the content of fiduciary loyalty. The comparative legal method was used to identify the peculiarities of the functioning of the institute of fiduciary duty of loyalty in foreign countries. The system and functional method were also used to sum up the results of the research.

Selection criteria. The selection of scientific sources, normative regulations and court practice of the Ukrainian Supreme Court was based on their relevance (from 2003 to the present), scientific level and relevance to the topic of fiduciary loyalty. The Supreme Court cases included in the analysis were selected based on the criterion of references to fiduciary duties and the scope of court's interpretation of the essence of fiduciary loyalty.

Validation methods. To verify the validity of the theoretical conclusions, methodological approaches to validation were applied, including internal validation by comparing data obtained from several sources. In addition, the assessment of the research results was based on the criteria of scientific accuracy, consistency and compliance with case law. Moreover, the results of the research are in full compliance with OECD approaches, the US and UK courts' judicial practice, which ensures that the elaborated conclusions follow the best practices in the sphere of corporate governance and fiduciary law.

Literature and legislation review

So, what does it mean for a fiduciary to act loyally with respect to the principal (beneficiary)? The OECD Principles of Corporate Governance (OECD, 2023) do not explicitly define the duty of loyalty. The Ukrainian Corporate Governance Code (Decision No. 118, 2020) states that "the duty of loyalty to the Company requires the members of the Supervisory Board to act in the best interests of the Company, which is often interpreted as a duty to act in the best interests of shareholders. It requires the Supervisory Board to act without a conflict of interests". The Methodological Recommendations (Decision No. 814-rsh, 2018) also define a number of prescriptive obligations.

And while the prohibitive rules are formulated in a clear and understandable manner and their nature allows court verification of only compliance, the obligation to act in the interests of the company remains vague, which raises the question of how a fiduciary should know whether he acts in the best interests of the company or not?

From a doctrinal perspective, there are several ways to overcome this uncertainty. First, it would be appropriate to consider the approach proposed by Professor Matthew Conaglen. The author has analysed a number of specific fiduciary duties (Conaglen, 2010) and came to the conclusion that only the duty of

prohibition of fiduciary conflict and the principle of (prohibition of) profit are specific ones (Conaglen, 2010, p. 61). Identifying loyalty with these prohibitions, Professor Matthew Conaglen wrote that "the fiduciary concept of loyalty is best explicated by reference to duties that are peculiar to fiduciaries, and which thus comprise the concept of fiduciary loyalty, rather than by reference to some abstract definition of loyalty" (Conaglen, 2010, p. 61).

The author believes that the non-conflict and non-profit rules serve a preventive function, which is to ensure that the fiduciary fulfils its non-fiduciary duties in a conscientious manner (Conaglen, 2010, p. 62).

Proposed approach contains a very simple idea: every fiduciary has fiduciary and non-fiduciary duties, the latter being those duties related to the fiduciary's competence in the area in which he or she exercises discretion. The fiduciary duty of loyalty is replaced by two prohibitions: not to act in a conflict of interest and not to receive unauthorised profit using his / her fiduciary position. The preventive function of fiduciary loyalty is realised through the fact that any actions and transactions of a fiduciary, committed in situation of the conflict of interests are presumed to be illegal and may be declared invalid by a court, regardless of whether they resulted in losses or were committed solely for the benefit of the beneficiary. The severity of these rules is absolute: the invalidity of a transaction entered in violation of the conflict-free rule does not depend on a breach of non-fiduciary duties or the beneficiary's inability to receive income from certain activities.

The second approach seems to be more structured, though not less understandable. Professor Lionel Smith equates loyalty with the duty to act in the best interests of the beneficiary (Smith, 2014, p. 158). The author writes that a legal duty, unlike a duty of virtue, must be clearly defined to be objectively verified if it had been fulfilled. Since the duty to act in the best interests of the beneficiary is formulated too broadly and does not offer a clear model of behavior, he considers it not as a specific requirement (duty) to the fiduciary's decisions, but as *a necessary way* of adopting such decisions. Professor Lionel Smith offers the following definition of fiduciary relations: "fiduciary relationships are all and only relationships in which powers are held that can only be exercised unassailably if they are exercised in what one perceives to be the interests of another", emphasising that loyalty is the defining feature of fiduciary relations, as it is an integral part of the powers of fiduciaries (Smith, 2014, pp. 157-158). Unlike the rules of prohibition of profit and conflict of interests, which might be cancelled or amended by the parties, the exclusion of the duty of loyalty leads to the destruction of the fiduciary relationship as is. Considering on the nature of the rules of loyalty, prohibition of profit and conflict of interests, Professor Lionel Smith writes that they are not actually duties, neither prescriptive nor prohibitive, but are in fact legal rules that regulate the discretionary powers of each fiduciary (Smith, 2014, p. 157). The regulatory effect of, for example, a no-conflict rule is that it prevents a fiduciary from exercising his or her authority in conflict situations. Professor James Penner takes a similar approach, calling the fiduciary's duty to make decisions only in the best interests of the principal a "necessary fiduciary norm" (Penner, 2019, p. 793).

The proposed approach is based on a nuanced understanding of the legal nature of an obligation: the existence of a legal obligation on one person means that another person has the right to demand compliance with the relevant standard of behaviour. At the same time, the author compares fiduciary duties with invalid transactions concluded under the influence of mistake or violence: the relevant legal rules governing the invalidity of such transactions do not require a person not to be mistaken or subjected to violence – they only state that there was a defect of will, which entails the invalidity of such an expression of will. Fiduciary duties perform a similar function: these are rules, the violation of which leads to the invalidity of transactions (and / or other legal consequences), which regulate the scope of the fiduciary's powers, as well as his / her rights to the results of the exercise of delegated powers (Smith, 2014, p. 153).

It is difficult to disagree that a fiduciary, due to the lack of a clearly defined model of behaviour, cannot be obliged to be loyal or not to make decisions in conditions of conflict of interest or not to receive unauthorised profits. The protective function of fiduciary law is aimed at correcting defects in the fiduciary's expression of will (or the scope of his / her powers), and not at his or her behaviour as such.

Professor Robert Sitkoff, relying on the developments of the scientific school of economics and law (in particular, the theory of incomplete contracts), presents a slightly different model of fiduciary duties. The author emphasises that fiduciary relations are one of the ways to reduce transaction costs that inevitably arise because of the engagement of fiduciary by the beneficiary in order for the fiduciary to exercise discretionary powers that affect the beneficiary's welfare.

In the proposed model, it is the court that is obliged to complete the contract ex post, deciding whether the fiduciary acted in accordance with the parties' agreement. The author divides all fiduciary duties into primary and secondary duties. The main fiduciary duties are loyalty and care. These rules are formulated as open standards (Sitkoff, 2019, pp. 424-425).

There are also ancillary fiduciary duties, which are formulated as specific rules of conduct, the variety of which depends on the scope of the fiduciary relationship. The author, for example, refers to the following ancillary fiduciary duties as the rules of prohibition of conflict of interests and profit (Sitkoff, 2019, pp. 426-427).

Ancillary (secondary) fiduciary duties simplify the application of fiduciary rules and thus reduce transaction costs, while primary fiduciary duties ensure compliance with the legal regime of fiduciary relations in all other cases, albeit with higher transaction costs.

Thus, the author proposes a two-tier structure of fiduciary duties which are interrelated as standards (basic fiduciary duties of loyalty and care) and rules (ancillary fiduciary duties).

Professor Andrew Gold also worked on the problems of fiduciary loyalty, namely he had analysed a number of concepts of loyalty in search of the minimum content of this duty. He wrote that loyalty might be regarded as avoidance of fiduciary conflicts, as a positive commitment to the interests of the beneficiary, as truthfulness, as a condition in a hypothetical contract, loyalty as fairness (Gold, 2014, pp. 178-182).

Each of the above theories of fiduciary loyalty has certain weaknesses: for example, loyalty cannot be considered solely in the light of the rule of prohibition of fiduciary conflicts, since, for example, the corporate law of the United States of America allows limiting or even cancelling anti-conflict rules (in particular, in Delaware), which obviously does not mean that fiduciary relations between the members of a partnership or limited liability company cease to exist upon such limitation or cancellation (Gold, 2014, p. 184). Moreover, fiduciary loyalty also includes the obligation to act in good faith (CaseBriefs, 2006), which means that a corporate director may act in the absence of a conflict of interest and at the same time be disloyal if his actions are not in good faith. In fact, the English courts take the same position (Bailii, 1996).

In general, the author believes that there is no specific concept of loyalty that could cover all types of fiduciary relationships, but loyalty remains an integral feature of fiduciary relationships. The fact is that some fiduciary relationships may require unconditional loyalty, regardless of the existence of a conflict of interest, while others will focus on a strict prohibition of conflicts of interest, regardless of unconditional loyalty; some relationships may allow 'white lies', while others do not (Gold, 2014, p. 191). Finally, the author concludes that "directedness toward a beneficiary may ordinarily be a minimal requirement, and perhaps loyalty means that a fiduciary must not breach the trust that is characteristic of a particular relationship, but theorists are usually looking for something more" (Gold, 2014, p. 194).

Does the work of Professor Andrew Gold mean that it is impossible to formulate a minimum definition of the fiduciary duty of loyalty? In our opinion, no. The inclusion or exclusion of certain rules in certain types of relations (for example, the rule to act in the best interests of the principal in corporate relations) changes the scope of the fiduciary's powers but does not change the content of the fiduciary duty of loyalty itself.

Results and discussion

Starting the discussion on the fiduciary duty of loyalty, primarily, it is necessary to determine whether it is a duty. In our opinion, Professor Lionel Smith has provided sufficient arguments to show that the duty of loyalty in the strict legal sense is not a legal duty, as it does not correspond to a particular model of behaviour to which a fiduciary can be obliged to comply through recourse of court proceedings. Loyalty is a legal standard enforced by a number of rules, including rules prohibiting the receipt of unauthorised income and conflict of interests.

The purpose of the legal standard of loyalty is to ensure that the results of the fiduciary's operations are attributable to the beneficiary's property or non-property interests.

This idea is not new: its basis can be found in the work of Professor Julian Velasco, who, during the test of his fiduciary powers theory on the cases of trustees and agents, formulated the following definition of fiduciary relations: "a fiduciary relationship is one in which one party (the fiduciary) *has power, in the form of substitutive exercise of legal capacity*, over the significant practical interests of another (the beneficiary)" (Velasco, 2018, p. 86), and Professor Paul Miller wrote that fiduciaries exercise derivative powers when they make decisions for others who have given them the power to act at their own discretion, which means that the exercise of fiduciary powers is nothing more than *an extension of the capacity of the person establishing the fiduciary relationship* (Miller, 2018, p. 191).

Regardless of whether the beneficiary's legal capacity is being extended or substituted, the main feature of fiduciary relations is that they are performed in the interests of the beneficiaries. In this regard, Professor Paul Miller has written that "fiduciaries "owe" the benefit of their judgment to another (beneficiary or benefactor / grantor) precisely because their powers can best be understood normatively as a means belonging rightfully to the grantor, to be exercised for ends that he has specified (which ends may include creation of a beneficial interest and right in beneficiaries named by the grantor)" (Miller, 2018, p. 191).

The attributive feature of the fiduciary duty of loyalty explains the formation of the non-profit and no-conflict rules: each of these rules protects the beneficiary from the loss of his or her property or non-property interests. The non-conflict rule usually is applied with the aim to prohibit fiduciary from receiving unauthorised profit, and the non-profit principle applies if such profit is received, however the option of conflict of interests without receipt of unauthorised profit is also available.

The attribution of the fiduciary's decisions to the beneficiary's interests also explains why fiduciary loyalty is often associated with the "act in the best interests" rule. However, there is still a discussion whether it should be in the "best" or "sole" interest of the beneficiary.

Professor Tamar Frankel writes that the traditional duty of loyalty required a fiduciary to act not in the "best", but in the "sole" interests of the beneficiary. In the author's opinion, the "sole interests of the beneficiary" required full and unconditional devotion to the beneficiary's interests, and not the fiduciary's own interests. At the same time, the "best interests" focuses not on the beneficiary's personality, but on such features as experience, attention, and avoidance of negligent behavior on fiduciary's side. The change in emphasis leads to the transformation of loyalty into a duty of "care", which is much closer to the fiduciary duty of care, requiring fiduciaries to exercise their powers with care, professionalism, and competence. Professor Tamar Frankel regards the wording "in the best interests" as a threat, because it origins a sense of partnership between fiduciary and beneficiary, which, in its turn, may lead the fiduciary to act on such principles like "what is best for you can be best for me as well", and "what is best for me can be also best for you as well" (Frankel, 2014, pp. 249-250). It appears that the author's criticism is fair, and the difficulty of identifying the minimum content of loyalty is complicated by the partial mixture of its content with the fiduciary duty of care.

However, the application of fiduciary loyalty is not limited to the above examples, as Professor Hillary Sale writes, the duty of good faith as a component of fiduciary loyalty, "grown[ed] over time into a role of policing the space between the duty of care and traditional loyalty duties" (Sale, 2019, p. 763). In our opinion, the duty of good faith has been turned into an antagonist of the duty of care and the business judgement doctrine: the boost for the development of the separate duty of good faith, within fiduciary loyalty, was the court judgment in Smith v. Van Gorkom (CaseBriefs, 1985), that was considered in Delaware, and according to which the case was reversed and remanded for further proceedings in order to assess the personal liability of directors. The said decision attracted such kind of attention that the Delaware state lawmakers responded by adopting the following provision on exemption from liability:

Thus, fiduciary loyalty, in addition to its inherent function of attributing the results of the fiduciary's decisions to the beneficiary's interests, and its part – the duty of good faith, have been opposed to the limitations, imposed on fiduciary duty of care.

Professor Hillary Sale writes that the case law has filled in the gaps in what exactly good faith means as a part of fiduciary loyalty (Sale, 2019), for instance:

1) The behaviour of directors is in a good faith if they have established appropriate monitoring, compliance and internal control systems;

2) The following acts should be regarded as committed not in a good faith: intentional actions "with a purpose other than that of advancing the best interests of the corporation", "acts with the intent to violate positive applicable law" and failure to act "in the face of a known duty to act, demonstrating a conscious disregard for";
3) Intentional violation of the law (namely, an environmental law), even if it is profitable for the company, goes beyond the scope of the duty of good faith of corporate directors;
4) Deliberate neglect by corporate directors to be informed about the business and its risks, despite the creation of a monitoring system;
5) The fiduciary's behaviour was "so far beyond the bounds of reasonable judgment that it seems essentially inexplicable on any ground other than bad faith", withal in that case the court took into account such factors as the fact that the fiduciary did not keep documentation for the trust, did not charge interest on loans, borrowed from the trust property, invested heavily in a company that depended on one client for 97% of its income, did not insist on obtaining collateral, ignored the steady decline in investment returns.

The said above indicates that a corporate law has formed a duty of good faith as an integral part of the fiduciary duty of loyalty, which has a different content compared to the requirements of good faith used by contract law or as a general principle of civil law, as provided for by the CCU. Fiduciary good faith is functionally aimed at preventing abuse of the right related to the limitation of civil liability for the breach of fiduciary duties. Withal, the content of the fiduciary duties of care and loyalty is being further intermixed and it obviously creates problems in developing a unified concept of the minimum content of the duty of loyalty. Should the principle of good faith supposed to be developed within the framework of fiduciary loyalty? This is a rhetorical question, but it can be said that classical loyalty has always been associated with the identity of the fiduciary and the attribution of his decisions to the interests of the beneficiary, while the duty of good faith in corporate law, as can be seen from the above examples, does not directly concern the identity of the beneficiary, to a lesser extent concerns the fiduciary, and is mainly concerned with the assessment of business decisions of corporate directors *ex post*, which is usually attributed with the scope of the fiduciary duty of care.

Conclusions

The fiduciary duty of loyalty is not a duty in the civil law understanding of the term, but rather a legal standard. This is because loyalty is too broad concept and does not imply a specific model of behaviour, and therefore the court cannot oblige a fiduciary to behave loyally towards the beneficiary. The main feature of loyalty is the attribution of the fiduciary's decisions to the beneficiary's interests, which logically follows from the fact that the fiduciary exercises derivative, delegated powers, and the results of such activities are appropriated by the beneficiary. Traditionally, it was believed that a fiduciary should follow the beneficiary's sole interests, but currently, most legal instruments on fiduciary duties use the term "best interests", which seems to be not the best practice, as it distracts a potential fiduciary from the beneficiary's personality and mixes the substance content of the fiduciary duties of loyalty and care. The non-profit and non-conflict rules, rules on reporting of potential conflicts of interest, return of unauthorised profits and other rules, the specific set of which depends on the sphere of origin of fiduciary relationship, are auxiliary, preventive legal mechanisms designed to ensure that the fiduciary makes decisions in the best interests of the beneficiary. In some jurisdictions, such as the United States of America, corporate law allows for the limitation of corporate directors' liability for the breach of fiduciary duty. The doctrine of the duty of good faith, as an integral part of fiduciary loyalty, has been developed with the aim to prevent the abuse of such limitations. The court practice has formed the content of "fiduciary good faith", which is different from the general civil or contractual understanding of this term. Fiduciary good faith seems to be more functionally focused on *ex post* assessment of corporate directors' decisions, which leads to overlap with the functional scope of the fiduciary duty of care. It appears that the intertwining of the content of the duties of care and loyalty significantly complicates the doctrinal understanding of loyalty as a legal mechanism for appropriation of the results of the fiduciary's activities by the beneficiary. Returning to the question posed at the beginning of this article "what does it mean to act loyally?" or "in the best interests of the principal", the following answer is proposed: in a narrow sense - not to encroach on property and non-property benefits, which were delegated by beneficiary to the fiduciary for the management or obtained as a result of such management, and in a broad sense (however, limited in scope to corporate law only), the proposed answer should be supplemented with the phrase "the fiduciary duty of good faith, which prohibits intentionally breaking the law, even if it is in the beneficiary's interest, deliberately neglecting directors' duties, obliges

to establish effective monitoring and compliance systems and to take other actions aimed at making lawful and informed decisions, shall also be taken into consideration".

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An eye for artificial intelligence: Insights into the impact of strategic leadership on intellectual capital of administrative leaders in King Saud University

نظرة في الذكاء الاصطناعي: رؤى حول تأثير القيادة الاستراتيجية على رأس المال الفكري للقيادات الإدارية في جامعة الملك سعود

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Abstract

The aim is to investigate the impact of strategic leadership on intellectual capital of administrative leaders in King Saud University. The study is a cross-sectional descriptive research. It utilizes a quantitative approach. It will prove the cause and effect relationship between strategic leadership and intellectual capital. The statistical population of this research was faculty members of King Saud University (n=220 people) in the academic year 2024-2025. Strategy development has an impact on human capital and structural capital (components of intellectual capital), while it does not affect the customer capital component. Strategy implementation affects the human capital and structural capital components of intellectual capital, while it does not affect the customer capital component. Strategy evaluation affects human capital and structural capital; While it does not affect the customer's capital component. According to the results of the implementation of the strategy evaluation step, it can increase human capital and structural capital in the university. According to the results of the structural equation model presented, the generality of the study was confirmed and the impact of the stages of the strategic management process on the components of intellectual capital was high. Intellectual capital (human, structural and customer) is a category whose emergence, improvement and preservation in organizations requires time and precise long-term planning.

Keywords: Artificial intelligence, strategic leadership, intellectual capital, administrative leaders.

الملخص

هدفت الدراسة الى معرفة أثر القيادة الاستراتيجية على رأس المال الفكري للقيادات الإدارية بجامعة الملك سعود. الدراسة وصفية عبر قطاعية ،تستخدم المنهج الكمي، تبحث فى العلاقة السببية بين القيادة الاستراتيجية ورأس المال الفكري. المجتمع الإحصائي لهذا البحث هو أعضاء هيئة التدريس بجامعة الملك سعود (220 شخصًا) في العام الدراسي 2024-2025. يؤثر تطوير الاستراتيجية على رأس المال البشري ورأس المال البنائى (مكونات رأس المال الفكري)، في حين أنه لا يؤثر على مكون رأس مال العميل. يؤثر تنفيذ الاستراتيجية على رأس المال البشري ورأس المال البنائى لرأس المال الفكري، في حين أنه لا يؤثر على مكون رأس مال العميل. يؤثر تقييم الاستراتيجية على رأس المال البشري ورأس المال البنائى ؛ في حين أنه لا يؤثر على مكون رأس مال العميل. وفقًا لنتائج تنفيذ خطوة تقييم الاستراتيجية، يمكن أن تزيد من رأس المال البشري ورأس المال البنائى في الجامعة. وفقًا لنتائج نموذج المعادلة البنائية المقدم، تم تأكيد عمومية الدراسة وكان تأثير مراحل عملية الإدارة الاستراتيجية على مكونات رأس المال الفكري مرتفعًا. رأس المال الفكري (البشري والبنائى والعميلي) هو فئة يتطلب ظهورها وتحسينها والحفاظ عليها في المنظمات الوقت والتخطيط الدقيق على المدى الطويل.

الكلمات المفتاحية: الذكاء الاصطناعي، القيادة الاستراتيجية، رأس المال الفكري، القادة الإداريون

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Introduction

Strategic leadership and Intellectual Capital

The modern era is witnessing many rapid and multiple developments and changes, as a result of the revolution in information, communications and technology and the speed of their updating. Today's educational institutions belong to this rapid environment (Konca & Hakyemez-Paul, 2021; Tut et al., 2021). With the passage of the first two decades of the twenty-first century, events have followed one another, which has made it difficult for educational institutions to control or monopolize intellectual capital, because the era that these institutions are currently living in is the era of the renaissance of science and knowledge.

As a result of the pressures imposed by these events, educational institutions had to shift towards new institutional patterns that are flexible and focus on science, thought, and intangible assets, or what is called intellectual capital, in generating value (Akyol & Ulutaş, 2021). Intellectual capital represents a set of experiences, skills, talents, processes, structures, work systems, procedures, and a network of relationships that an institution possesses, which can be employed to achieve its goals efficiently and effectively (Al-Eissa & Alshhry, 2020; Mehralian et al., 2024).

Strategic leadership (Silman, 2015) occupies a very important role in the development of education and the development of human resources in educational institutions (Mohamed Mostafa, 2014), as these institutions face multiple challenges in dealing with the various changes of the era (Akyol & Ulutaş, 2021), which require them to develop capabilities and bring about continuous change in line with the nature of the changing and complex environment and the nature of the competitive environment, and this requires leadership with a strategic vision and ability to assign knowledge to serve organizational goals (Rajbhandari, 2017).

The universities that are located on the pyramid of this confrontation are considered the cornerstone in building societies (Turhan & Güneyli, 2022), making their civilization and confusing their strategic future, as they are the top of the educational system, which bears the greatest role in facing these changes, in exchange for their intellectual human and technical capabilities. University institutions play the role entrusted to them in producing knowledge through scientific research in priority areas for economic and social growth locally and globally, especially in areas that are considered strategic (Śliwerski, 2016).

The goal of strategic leadership is not to repeat past successes; rather, its main goal is to overcome unexpected situations and solve environmental problems. It is clear that achieving the long-term goals of strategic leadership in universities is not possible except under the shadow of successful organizational knowledge management. One of the vital and strategic requirements of management in leading universities is access to outstanding human resources (dean, vice-chancellor, professors, staff, and students) armed with up-to-date organizational knowledge and information to achieve the main tasks of management and strategic decision-making (Mutiu & Yinka Calvin, 2022). The university contains a system of human resources with knowledge that have professional characteristics and, in a word, are considered the most key part of the organization's capital, which the science of managing this capital has called intellectual capital in recent decades (Tjahjadi et al., 2024).

Applications of Artificial Intelligence in Leadership

AI is becoming increasingly important for leaders in today's business world. Successful leaders are realizing the need to adopt an approach that focuses on both people and technology. In this context, AI technologies can make significant contributions to strategic and operational decision-making processes for leaders (Tjondronegoro et al., 2022). AI-based systems can support leaders to make more conscious, effective and accurate decisions. In addition, thanks to recent technological developments, AI is transforming leadership practices and representing a new era called "Leadership 4.0" (Hai & Van, 2021). AI-supported analysis tools can provide leaders with in-depth information about employee performance, motivation and engagement, so leaders can better understand the unique needs of each team member and personalize their management style to create a more collaborative and satisfying work environment (Buck & Morrow, 2018).

The integration of AI into leadership, decision-making and strategic management has begun to attract significant attention in recent years. As organizations attempt to adapt to rapidly changing markets, the role

of AI in shaping leadership styles, improving decision-making processes, and driving strategic initiatives has become a focal point in academic and professional discussions (Quaquebeke & Gerpott, 2023).

Problem Statement

Universities are the arenas of science and technology production and the scientific support for the economic, political and social growth of societies. Awareness of these matters requires serious attention to universities, their vision and mission, the style and method of goal setting and the way of planning and implementing these goals. And for success in these dimensions, serious attention should be paid to the individuals involved in them as the intellectual capital of universities. Today, the words workforce or human resources are no longer applied to the individuals of the organization, but they are considered as human capital. This belief stems from the extraordinary value added of intellectual capital in the organization. The need for universities today is to take measures to best utilize these capitals and to utilize their potential for planning and managing the future of organizations.

Literature on strategic leadership and intellectual capital is rare, and by reviewing it, one can realize the lack of attention paid by researchers to the discussion of strategic leadership in universities and the study of only some aspects of its process with intellectual capital. This has established the necessity of a coherent study in this field, and the present study has examined this issue.

Literature Review

The role of strategic leadership in intellectual capital

Leadership theories and research have a long history, but recently the role of leadership in knowledge management has begun to be articulated (Mutiu & Yinka Calvin, 2022). Organizational leaders can be effective in knowledge transfer processes (Aishah & Nor, 2022). They are not afraid of rapid change; in fact, they have embraced learning programs and know that effective management is not a matter of having more knowledge, but of knowing how to apply it. Therefore, leadership is a science and more than an art (Aishah & Nor, 2022). Strategic leadership plays an important role in promoting organizational knowledge, organizational performance, organizational effectiveness, organizational learning, organizational culture, creating insight, and managing knowledge and information (Mutiu & Yinka Calvin, 2022). Leadership, unlike influencing employee behavior, inspiring, and improving human relations, is considered to be a driver of communication between the components of intellectual capital management (Tyson, 2020).

In this competitive world, it is no longer appropriate to adhere to traditional leadership styles. Instead, it is necessary to pursue the missions of universities by having broad and deep perspectives and using strategy-oriented management. Among the leadership styles that can contribute significantly to the success of universities in today's organizational world of ups and downs is strategic leadership. Kebede et al. (2024) considers strategic leadership as integrated decisions and activities for developing effective strategies, implementing, controlling and evaluating results. Strategic leadership is integrated decisions and activities for developing effective strategies, implementing and controlling their results; therefore, activities related to examining, evaluating and selecting strategies, adopting any measures inside and outside the organization for implementing these strategies and finally controlling the activities carried out are called strategic leadership (Kebede et al., 2024). Strategic leadership is a process that knowledge It relates the organization to the following: the type of organizational structure design for the expansion and advancement of knowledge, organizational strategy, growth and development of individuals' knowledge specializations, and re-engineering of organizational structures.

One of the most important concepts in the information age is intellectual capital, which is defined as the collective brainpower or shared knowledge of the workforce. In this age, knowledge is an irreplaceable resource and the goal should always be to create and grow intellectual capital (Rajbhandari, 2017). Intellectual capital management focuses on creating and nurturing intellectual capital from strategic and practical perspectives. Nowadays, intellectual capital management has become one of the most important concerns in organizations and can develop organizations and improve organizational benefits (Aishah & Nor, 2022).

Intellectual capital management deals with the interaction of resources (tangible and intangible) to create maximum value, and leadership plays an important role in transforming the knowledge available in an

organization into intellectual capital (Tjahjadi et al., 2024). Therefore, it seems that the intersection point of knowledge leadership and intellectual capital management is the production and application of new knowledge and ideas in the organization, creativity and innovation, improving organizational learning, and organizational effectiveness. Today, paying attention to knowledge leadership and intellectual capital management in universities and higher education centers is doubly necessary and important; because the main role-playing element in the academic community is human resources, which, the more capable and knowledgeable they are, the better universities can achieve their vision and mission, which is the production of Science and technology in society (Tjahjadi et al., 2024). In order to achieve this goal and transform and promote employees into scholars, more attention should be paid to the accumulation of intellectual capital and use it for strategic planning and management. One of the most important effective factors in this field is strategic leadership; because strategic leadership, in addition to inspiring, empowering, and motivating employees, can integrate human resources and intellectual capital in universities by taking measures and achieving predetermined goals.

There is a great positive role for strategic leadership in building intellectual capital, and this result is natural because building intellectual capital can only take place with the presence of a strategic leadership that is interested in its human resource and works for its development. Previous studies have proven that there is a role for strategic leadership over intellectual capital (Slack & Munz, 2016).

AI in Educational Leadership

Artificial Intelligence (AI) has emerged as a transformative force in various sectors, revolutionizing the way tasks are performed and decisions are made. In the field of education, AI holds great promise for changing educational leadership practices and increasing organizational effectiveness.

In the field of education, AI is revolutionizing administrative tasks, instructional practices, and student support services. Educational leaders are increasingly turning to AI-based tools and platforms to streamline administrative workflows, optimize resource allocation, and increase organizational efficiency. From intelligent instructional systems that adapt to student learning needs to data analytics platforms that predict student outcomes, AI is changing the landscape of educational leadership. The proliferation of AI technologies presents educational leaders with unprecedented opportunities to improve student outcomes, foster innovation, and drive organizational change.

The importance of AI in educational management lies in its potential to address long-term challenges and accelerate transformative change. Traditional leadership practices in education often struggle with inefficiencies, limited resources, and complex decision-making processes. AI offers a paradigm shift by automating routine tasks, enhancing human decision-making capabilities, and opening up new possibilities for innovation. One of the key challenges is the lack of awareness and understanding among educational leaders about the capabilities and limitations of AI technologies. Many educational leaders may perceive AI as a complex and intimidating concept, leading to reluctance or resistance to its implementation.

Aims

The aim is to investigate the impact of strategic leadership on intellectual capital of administrative leaders in King Saud University.

Methodology

Research Design

The study is a cross-sectional descriptive research. It utilizes a quantitative approach. It will prove the cause and effect relationship between strategic leadership and intellectual capital.

Sample

The statistical population of this research was faculty members of King Saud University (n=220 people) in the academic year 2024-2025. The data collection tool was a researcher-made strategic management questionnaire with sixty seven questions and a researcher-made intellectual capital questionnaire with thirty five questions. Both questionnaires were prepared and used based on the study of theoretical foundations

and on the Likert scale. Considering that the aforementioned questionnaires were researcher-made, the opinions of experts in the fields of management, educational management, higher education management, and educational sciences were used to determine their face validity and content, and the Cronbach's alpha coefficient formula was used to determine their reliability, which resulted in 0.89 for the strategic management process and 0.93 for intellectual capital. Data analysis was performed using SPSS and Amos graphics statistical software, and regression analysis, MANWA analysis, and structural equation modeling were used.

To enhance the estimation of the minimum sample size, G*Power was utilized. With an effect size of 0.15, a significance level of 5%, and a statistical power of 80% (Mohammad et al., 2024), the analysis indicated that at least 92 participants were necessary. Consequently, the chosen sample size of 220 cases was deemed adequate.

Ethics approval

All procedures in studies involving human participants were performed in accordance with the ethical standards of the institution's Human Research Ethics Committee of King Saud university. Informed consent was obtained. Data privacy was ensured.

Pilot Testing

Using the self-report, structured questionnaire, pilot testing has been conducted to ensure that respondents understand all items.

Results

The findings related to the regression coefficient of the effect of strategic leadership process stages on intellectual capital components are presented in Tables 1 - 3.

Table 1.
Results of the regression coefficient of the effect of strategy development on intellectual capital components

	Standard Error	Regression Coefficient	t-Value	Coefficient of Determination	*P*
Human capital	0.18	0.32	4.55	0.72	0.000
Structural capital	0.15	0.54	7	0.72	0.000
Customer capital	0.25	0.05	0.77	0.72	0.45

Source: By the author

Table 1 shows that strategy development has an effect on human capital and structural capital with (<0.001), while it does not have an effect on the customer capital component with (P = 0.45). According to the results, implementing the strategy development step can increase human capital and structural capital in the university. The coefficient of determination shows that 0.72 of the changes in the scores of the two components of human capital and structural capital are affected by strategy formation.

Table 2.
Results of the regression coefficient of the effect of strategy implementation on intellectual capital components

	Standard Error	Regression Coefficient	t-Value	Coefficient of Determination	*P*
Human capital	0.19	0.31	3.50	0.57	0.000
Structural capital	0.15	0.43	4.44	0.57	0.000
Customer capital	0.27	0.08	1.40	0.11	0.18

Source: By the author

The results of Table 2 show that strategy implementation has an effect on human capital and structural capital, which are components of intellectual capital, with a P = 0.001, while it does not affect the customer capital component (P = 0.18). According to the results, implementing the strategy implementation step can increase human capital and structural capital in the university. The coefficient of determination shows that 0.57of the changes in the scores of the two components of human capital and structural capital are affected by strategy formation.

Table 3.
Results of the regression coefficient of the effect of strategy evaluation on intellectual capital components

	Standard Error	Regression Coefficient	t-Value	Coefficient of Determination	*P*
Human capital	0.12	0.19	2.18	0.57	0.03
Structural capital	0.09	0.60	6.57	0.57	0.001
Customer capital	0.18	0.09	0.40	0.10	0.73

Source: By the author

The results of Table 3 show that strategy evaluation has an effect on human capital (P = 0.03) and structural capital (P = 0.001) on the components of intellectual capital, while it does not affect the customer capital component. Therefore, the results of implementing the strategy evaluation step can lead to an increase in human capital and structural capital in the university. The coefficient of determination shows that 0.57 of the changes in the scores of the two components of human capital and structural capital are affected by strategy formation.

Table 4.
Results of the Relationship between Each of the Strategic Management Components and All of the Intellectual Capital Components

Strategic Leadership Process	Lambda Wilkes	F-coefficient	DF	P	coefficient of correlation	statistical power
Strategy development	0.80	20.12	3	0.001	0.24	0.99
Strategy Application	0.99	1.27	3	0.30	0.10	0.75
Strategy evaluation	0.95	5.20	3	0.002	0.19	0.94

Source: By the author

The f coefficients in Table 4 show that there is a positive and significant relationship between strategy development and all components of intellectual capital (P = 0.001) and the coefficient of correlation is 0.24.

There is also a positive and significant relationship between strategy evaluation and all components of intellectual capital (P = 0.002) and the coefficient of correlation is 0.19. However, there is no significant relationship between strategy application and all components of intellectual capital (P = 0.30) and the coefficient of correlation is 0.10.

Table 5.
Results of the relationship between each of the components of intellectual capital and all strategic leadership components

Components of intellectual capital	Sum of Squares	Degree of freedom	Mean of squares	F	P	coefficient of correlation	statistical power
Human capital	4684,211	3	1561,40	112,32	0.001	0.64	0.98
Structural capital	8839,32	3	2946,44	160,35	0.001	0.72	0.99
Customer capital	728,241	3	242,74	43,34	0.001	0.40	0.97

By the author

The findings in Table 5 show that there is a positive and significant relationship between all three components of intellectual capital with all stages of the strategic management process, and the statistical power (0.98, 0.99, and 0.97) indicated the adequacy of the sample size to test these hypotheses.

Table 6.
Estimating the significant difference of parameters with a value of zero

Parameter type	Estimate		Critical ratio CR	Significance level P-value
	Standard	Non-standard		
Gamma	0,92	0.39	17.827	0.000
Lambda x	0,96 0,87 0,89	1 0,77 0,54	 20.180 19.400	0.000
Lambda y	0,89 0,96 0,78	1 1.40 0.42	 20.700 12.800	0.000

By the author

As can be seen in Table 6, the value of the standardized gamma coefficient between strategic leadership and intellectual capital, and was 0.92 = Gamma 2, i.e. knowledge conversion process, which indicates a positive effect of 0.91 percent of the strategic leadership process on the intellectual capital components.

The calculated factor loadings (lambda parameters x and y) are also all different from zero, and a value higher than 0.7 for all of them indicates high accuracy in measuring the latent variables defined in the model. Overall, the results show that the strategy development indicator for strategic leadership with lambda x is 0.91 and the structural capital determinant for intellectual capital with lambda y 0.96 has a higher weight.

Discussion

The knowledge-based era, in which strategic insight and knowledge are considered the most important capital of organizations, requires a different management approach to organizational and employee issues. Universities have been the vanguard of development in every society that needs to have a transformational perspective and in order to reach a high level of development and bring society to the path of excellence, because according to theories, no fundamental change takes place in any society unless that change begins with its educational system.

Integrating AI into educational leadership offers numerous opportunities and benefits. AI-based analytics enable evidence-based decision-making, with real-time information and insights. By automating routine administrative tasks, AI frees up time and resources for educational leaders to focus on strategic initiatives and innovation (Picciano, 2017). AI-based personalized learning platforms respond to individual student needs, preferences, and learning styles, and enhance engagement and academic success (VanLehn, 2011). Furthermore, AI technologies facilitate collaboration, communication, and knowledge sharing among educational stakeholders, fostering a culture of continuous improvement and organizational learning (Picciano, 2017).

The findings in Table 1 show that strategy development has an impact on human capital and structural capital (components of intellectual capital), while it does not affect the customer capital component. According to the results, implementing the strategy development step can increase human capital and structural capital in the university. The results of the present study are somewhat consistent with the results of the studies of Rideg et al. (2023), and Belmonte da Silva et al. (2021).

Findings of Table 2 show that strategy implementation affects the human capital and structural capital components of intellectual capital, while it does not affect the customer capital component. According to the results of the implementation of the strategy, the implementation of the strategy can increase human capital and structural capital in the university. The results of the present study are somewhat consistent with the results of the studies of Saad (2020), Lee & Choi (2003). They do but sometimes The reasons for the failure of appropriate strategies in the implementation phase lie in the instability of environmental conditions, low expertise and commitment of implementers, considerate supervision, informal communication within and outside the university, lack of proper formal and human communication.

Table 3 shows that strategy evaluation affects human capital and structural capital; While it does not affect the customer's capital component. According to the results of the implementation of the strategy evaluation step, it can increase human capital and structural capital in the university. In addition to measuring the success of these strategies, the evaluation of the strategies developed and implemented also clarifies the role of human resources and the structure of universities, which can contribute to both better implementation of strategies and the promotion of intellectual capital. In order to fully evaluate the process of university activities, it is better for the university to adopt a procedure that involves the customers and stakeholders of the organization in this evaluation.

The findings in Table 4 show that there is a positive and significant relationship between strategy development and evaluation and all components of intellectual capital. The findings are consistent with Jaunanda et al. (2024). The findings showed that the strategy evaluation step had a positive effect on increasing intellectual capital; however, in the strategy implementation stage, where it is necessary to adopt the necessary policies, determine the necessary financial resources, provide the necessary support and motivation, and be prepared to accept and participate in the change process, there are weaknesses that, in

addition to disrupting the strategic leadership implementation process, did not have an effect on intellectual capital and did not show a significant relationship.

According to the findings in Table 5, it should be said that there is a positive and meaningful relationship between all three components of intellectual capital and all stages of the strategic management process. To move towards strategic leadership, the knowledge and skills, experiences and information, creativity and innovation of faculty members should be used, but to benefit from these abilities, it is necessary to change the university structure, hardware and software systems, laws and regulations, and management styles according to the needs.

According to the results of the structural equation model presented in Tables 6 the generality of the study was confirmed and the impact of the stages of the strategic management process on the components of intellectual capital was high. Intellectual capital (human, structural and customer) is a category whose emergence, improvement and preservation in organizations requires time and precise long-term planning. From a strategic perspective, it can be said that for the improvement and preservation of each component of intellectual capital, a strategic plan is needed that includes the stages of developing, applying and evaluating the strategy in order to achieve the goals. In the study of lambda coefficients x, the strongest indicator for strategic leadership is the strategy development stage. It is necessary to take a firm first step and design a successful process by considering (strengths, weaknesses, opportunities and threats) for all stages and components.

Conclusion

Furthermore, the integration of AI opens up new opportunities for collaboration, innovation, and knowledge sharing in the educational ecosystem (Picciano, 2017). Educational leaders can use AI-based platforms and networks to connect with peers, share best practices, and collaborate on joint projects and initiatives (Murchan & Siddiq, 2019). Furthermore, partnerships with AI companies, research institutions, and technology startups can stimulate innovation, drive technological advancements, and accelerate progress toward educational goals (Murchan & Siddiq, 2019). By embracing these opportunities and harnessing the potential of AI, educational leaders can lead their institutions toward greater excellence, effectiveness, and equity in educational management.

Practical implication and future research

If we take an expert look at the university structures and human resources available in them, it is natural that despite the presence of specialized forces armed with up-to-date strategic knowledge and the readiness of the university's professional structures, the ground for promoting intellectual capital in the strategy development stage is high, and the activity process of universities also shows this; however, the fact that customers, as the most important element of university life, remain oppressed and do not receive much attention requires special attention from those responsible. According to the theories of Although it is necessary for university stakeholders to actively participate in all stages of the strategic management process, a survey revealed a lack of awareness of this issue, and part of the reason for this can be attributed to the centralization of decision-making and power structures in universities.

The existence of a relationship between the stages of the strategic management process and the dimensions of human capital and the structure of intellectual capital is a confirmation of the universities' familiarity with strategic management and their strategy-oriented nature; however, it is necessary to provide the necessary training to improve this knowledge, to review university structures, and to pay close attention to customer capital.

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Factors affecting online learners' continuous learning intention: Structural equation based on expectation-confirmation model

العوامل المؤثرة على نية التعلم المستمر لدى المتعلمين عبر الإنترنت: المعادلة البنائية المبنية على نموذج التوقع والتأكيد

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Abstract

As the number of online learning users continues to grow, exploring how to generate and maintain users' willingness to continue learning and improving user retention rates has become an important condition for the effective development of online learning. Based on the Expectation -Confirmation Model perspective, this study explores the impact of expectation confirmation, learning satisfaction, perceived usefulness, curiosity, and attitude on online learners' willingness to continue learning. Using structural equation model analysis, it is found that attitude has an important impact on continued learning willingness. Expectation confirmation, learning satisfaction, and curiosity have a certain impact on continuous learning intention, while perceived usefulness has no impact on continuous learning intention. Based on the above research findings, this study puts forward four suggestions to enhance online learners' willingness to continue learning.

Keywords: Continuous Learning Intention, Structural Equation, Expectation -Confirmation Model, online learning, continued learning willingness.

الملخص

مع استمرار نمو عدد مستخدمي التعلم عبر الإنترنت، أصبح استكشاف كيفية توليد والحفاظ على رغبة المستخدمين في مواصلة التعلم وتحسين معدلات الاحتفاظ بالمستخدمين شرطًا مهمًا للتطوير الفعال للتعلم عبر الإنترنت. استنادًا إلى منظور نموذج التوقع والتأكيد، تستكشف هذه الدراسة تأثير تأكيد التوقع والرضا عن التعلم والفائدة المدركة والفضول والاتجاه على رغبة المتعلمين عبر الإنترنت في مواصلة التعلم. باستخدام تحليل نموذج المعادلة البنائية، وجد أن الاتجاه له تأثير دال على رغبة التعلم المستمر. إن تأكيد التوقع والرضا عن التعلم والفضول لها تأثير معين على نية التعلم المستمر، في حين أن الفائدة المدركة ليس لها تأثير على نية التعلم المستمر. بناءً على نتائج البحث المذكورة أعلاه، تطرح هذه الدراسة أربعة اقتراحات لتعزيز رغبة المتعلمين عبر الإنترنت في مواصلة التعلم.

الكلمات المفتاحية: نية التعلم المستمر، المعادلة البائية، نموذج التوقع والتأكيد، التعلم عبر الإنترنت، الرغبة فى التعلم المستمر.

Introduction

During the epidemic, online education applications showed explosive growth, and the number of online learning users surged (Demir & İlhan, 2022). Relevant scholars pointed out that in future education and teaching, online learning is bound to become the "normal" of teaching and learning (Aristovnik et al., 2023; Mhlanga, 2024). Although online education is developing rapidly and the number of online learning users is also increasing year by year, serious practical problems have also been exposed in the prosperous development situation, namely, the problem of high learner participation rate, low completion rate and extremely high dropout rate (Demir et al., 2023; Yakar, 2021).

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These practical problems will not only affect the future development model and application practice of courses, but may even hinder the sustainable development of online education. It can be said that learners' participation in online learning has only made preliminary progress, and learners' continuous learning online can maximize the value of online educational resources (Timuçin & Tatlı, 2024). Researchers have carried out relevant research on the issue of learners' continuous learning online (Gündoğan, 2021). Most of them are mainly based on different theoretical foundations and research frameworks, and have conducted relevant empirical research from the perspective of factors affecting online learners' willingness to continue learning and proposed corresponding strategies and suggestions to promote learners' continuous learning behavior (Özkan et al., 2023; Tahoon, 2021).

However, some of the learners' own factors, who are the main body of online learning, are often easily overlooked, and these overlooked factors may be the key factors that affect online learners' willingness to continue learning (Kahramanoğlu & Dursun, 2022). Based on this, this study takes the Expectation Confirmation Model (ECM; Hariguna et al., 2023), which is widely used in various information systems to influence individuals' continued use intentions, as the theoretical basis, and introduces two learners' own factors, attitude and curiosity, to expand the ECM, explore the factors and variables that affect online learners' willingness to continue learning, in order to provide reference for subsequent research.

In the Arabic world, there is no study to my knowledge that dealt with factors affecting online learners' continuous learning intention based on expectation-confirmation model. The contribution of this study is that it analyzes the influencing factors and influencing mechanisms of online learners' willingness to continue learning . It is important to help online learners to generate continuous learning intention and maintain learning behavior. Therefore, improving the degree of consistency between individual expectations and reality, maintaining individual desire for knowledge and exploration, and improving online learning satisfaction can have a certain impact on online learners' willingness to continue learning.

Literature Review

Research on online learners' willingness to continue learning

The online learner's willingness to continue learning refers to the learner's willingness and intention to continue participating in the online learning until completion and to participate in the next online learning after participating in an online learning session. The generation of continuous learning intention is an important prerequisite and foundation for the generation of online learners' continuous learning behavior (Özkan et al., 2023). Researchers have conducted research on the relationship between relevant variables and online learners' willingness to continue learning from different theoretical perspectives. Based on the theoretical framework in the field of psychology about the individual's psychological decision-making process after being stimulated, namely "stimulus-organism-response" (S-O-R), from the teacher's online learning support, the learner's perceived interactivity, perceived usefulness and perceived ease of use (Hossain et al., 2024).

The flow experience of the learning process, and the technical environment characteristics of the MOOC platform to explore the impact mechanism of these variables on MOOC course learners' learning intention (Liu et al., 2023). Based on an improved technology acceptance model, namely the Integrated Technology Acceptance Model (UTAUT), the impact of performance expectations, effort expectations, community response, cooperation, and perceived value on online learners' willingness to continue learning was explored (Patil & Undale, 2023). From the theoretical perspective of psychological resistance, the impact of perceived scarcity, perceived lack of control, psychological resistance, and focused video lectures on MOOC learners' continuation intentions was explored (Azevedo et al., 2024). Or it integrates multiple theoretical models and explores the impact of each variable in the integrated model on MOOC learners' willingness to continue learning (Zhang et al., 2022).

In addition, there are studies that attribute the variables that affect MOOC learners' willingness to continue learning to the learners' own subjective factors such as learner motivation, personal experience, and perception, as well as the objective factors of teaching and management such as course design and platform management (Ram et al., 2023). Throughout the existing research, domestic and foreign researchers have determined the relationship between corresponding variables and online learners' willingness to continue learning from different theoretical perspectives and integrated models. Among them, the Technology Acceptance Model (TAM), S-O-R, and Flow Experience. There are many applications of theoretical

models, and judging from the current research results, research results are more abundant than domestic ones (Marikyan & Papagiannidis, 2023). It can also be seen that the change in research perspective provides a possible direction for further exploration of this topic.

Although some researchers have explored the influencing factors of continuous learning intention in MOOC environments based on ECM, such as exploring the impact of MOOC learners' expectation confirmation, learners' perceived usefulness, perceived ease of use and learning satisfaction on their continuous learning intention (Alhwaiti, 2023; Cheng, 2023), but first of all, ECM was initially used in the field of marketing, and the application of its model should be examined and explored when introduced in the field of education. sexual issues, and existing research has not explained the rationality of the ECM architecture; secondly, in the existing related research that explores learners' continuous learning willingness in online learning environments based on the ECM model, few consider learners' participation in online learning. Specific intrinsic driving forces, such as curiosity, may directly affect learners' willingness to continue learning, and all of the above research topics can be further explored.

ECM and its application research

ECM, the expectation confirmation model, is a theoretical model proposed by Bhattacherjee (2001) based on the expectation confirmation theory of Oliver (1980) (see Figure 1). This model believes that when information technology users consider continued use decisions, they are similar to consumers' re-consumption and purchase decisions in the field of marketing. Information system users' expectations for the information system and the actual experience results of the first use are both. The difference will affect the user's decision and intention to use again or continue to use. In addition, Bhattacherjee uses the perceived usefulness of the technology acceptance model to represent the cognitive expectations of information system use, and believes that this cognitive expectation will guide or influence the subsequent process of intention formation (Shukla et al., 2023). Currently, ECM has been used by researchers to explore issues related to users' continued use decisions and intentions in information systems or information technology, such as explaining and predicting learners' continued use intentions of digital textbooks, online education platform users' continued use intentions, and network Learners' willingness to continue using the learning space, etc. Therefore, this study will explore the continuous learning intention of online learning users, that is, online learners, based on ECM theory.

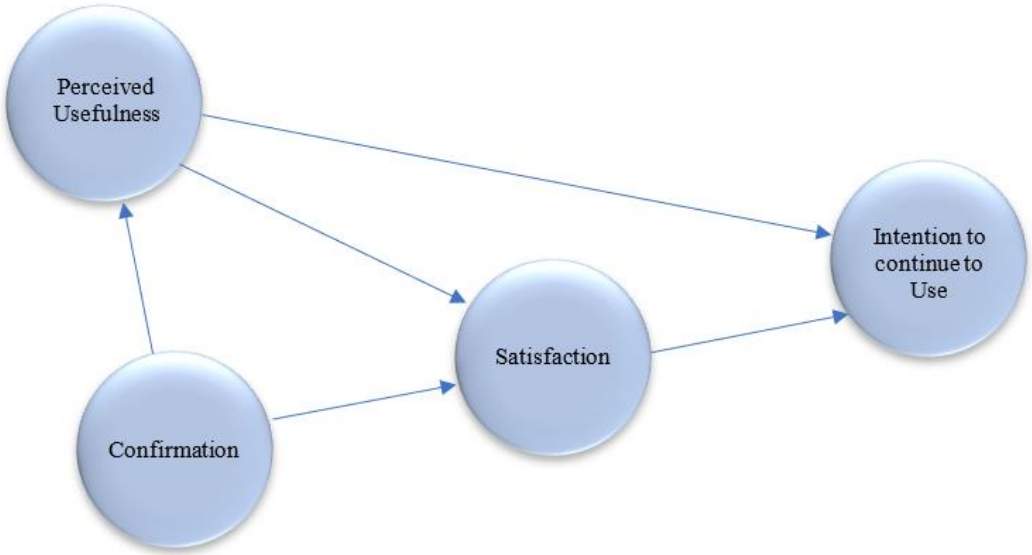


Figure 1. Expectation confirmation model
Source: (Bhattacherjee, 2001)

In ECM, Bhattacherjee & Premkumar (2004) used the perceived usefulness in TAM proposed by Davis (1989) to represent the initial expectations in the expectation confirmation theory, and believed that the perceived usefulness of information system users will affect the formation of their satisfaction, but Bhattacherjee & Premkumar (2004), in subsequent research, deleted the relationship path between perceived usefulness and satisfaction. In addition, some relevant researchers found that the relationship between perceived usefulness and satisfaction was not significant (Lin &Yu, 2023). Based on the above

discussion, this study believes that perceived usefulness has no impact on satisfaction and proposes the following hypothesis:

H1: Expectation confirmation has a significant positive impact on learning satisfaction.
H2: Expectation confirmation has a significant positive impact on perceived usefulness.
H3: Perceived usefulness has a significant positive impact on online learners' willingness to continue learning.

Attitude

Some studies believe that the role of satisfaction in ECM is similar to the role of attitude in TAM, and is a prerequisite for influencing users' continued use intention (Liu et al., 2023). Some researchers also believe that attitude is an emotional response based on satisfaction (Baba-Nalikant et al., 2023), and in order to improve the accuracy of behavioral prediction, the measurement of behavioral intention must be consistent with the specific behavioral response, while attitude is an emotional response to a specific behavior, may be more effective than satisfaction in measuring behavioral intention (Sarintohe et al., 2023).

Based on this, this study believes that compared with satisfaction, attitude is a factor variable that more directly affects individual behavioral intention, and the impact of satisfaction on individual behavioral intention is transferred through attitude. In addition, based on the conclusion that attitude in TAM can be used as a mediating variable to link individuals' perceived usefulness and intention to continue using (Davis et al., 1989), this study proposes the following hypothesis:

H4: Perceived usefulness has a significant positive effect on attitude.
H5: Satisfaction has a significant positive effect on attitude.
H6: Attitude has a significant positive effect on online learners' willingness to continue learning.

Curiosity

Studies have shown that most learners' motivation to participate in online learning is driven by interest (Hellín et al., 2023), and curiosity is found to be the internal motivation for learners to participate in and complete online learning (Dubey et al, 2023), and is also an important reason that affects learners' continuous learning (Ainley et al., 2002). It can be said that for some online learners, the desire for knowledge in a certain field or topic, that is, curiosity, may be an important internal driving force for them to participate in and complete online learning (Watted & Barak, 2018). Based on this, this study integrates the variable of curiosity into ECM and assumes that it serves as an intrinsic motivation and works together with the extrinsic motivation of perceived usefulness to influence attitude and continuous learning intention. In addition, based on the classification of curiosity, this study uses cognitive curiosity, which is more relevant to online course learning, as the main measurement variable and puts forward the following hypotheses:

H7: Curiosity has a significant positive impact on attitude.
H8: Curiosity has a significant positive impact on online learners' willingness to continue learning.

Collectively, literature shows a lot of factors affecting the willingness to continue using online learning. For example, the results of Bajaber (2024) show that the greatest influence on willingness to continue using online learning is ability, then motivation, and finally opportunity. Interests and hobbies among motivation factors, course quality, perceived cost, and social influence among opportunity factors, and learners' self-efficacy and meta-recognition among ability factors all have a significant impact on learners' continued willingness to learn online, knowledge needs, and achievements. However, no other study constructed a research model on factors influencing online learners' continuous learning intention from the perspective of ECM in Saudi Arabia.

Based on the above discussion, analysis and related assumptions, this study constructed a research model on factors influencing online learners' continuous learning intention from the perspective of ECM (see Figure 2).

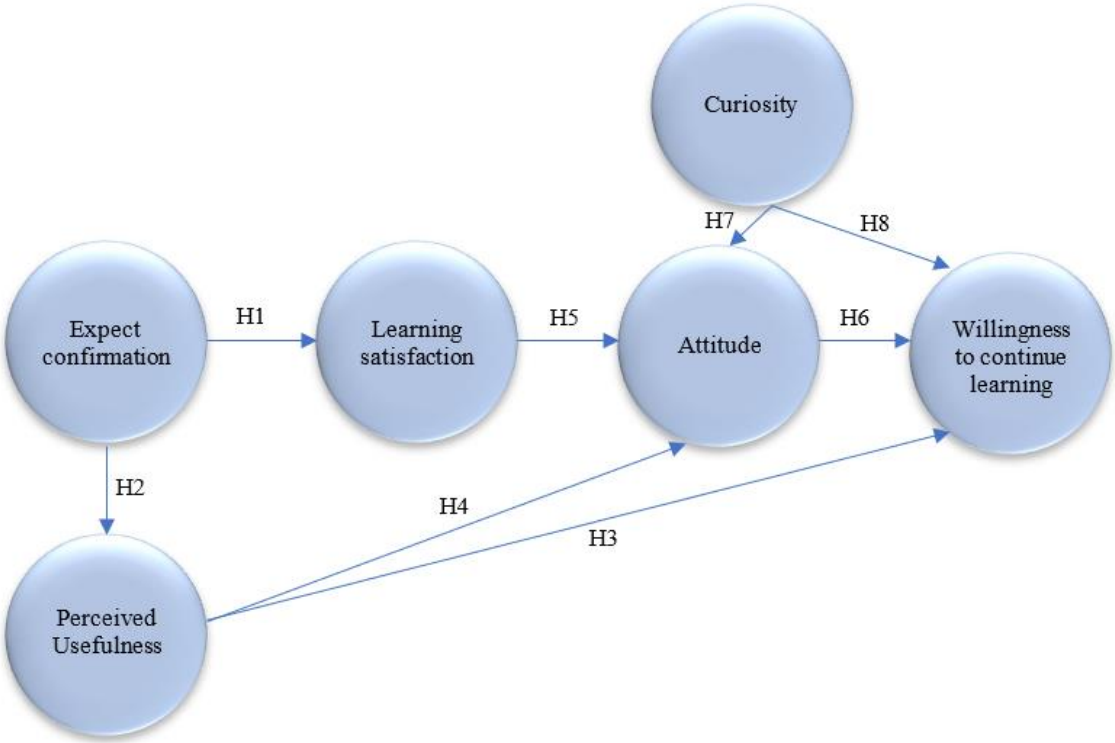


Figure 2. Research model on factors influencing online learners' willingness to continue learning.

Method

This survey study was used to explain factors affecting online learners' continuous learning intention based on expectation-confirmation model. Analysis of the structural model and hypotheses testing were used.

Participants and procedures

A total of 490 electronic questionnaires were collected. Based on the screening criteria of having online learning experience and excessive repetition of answers to measurement questions, 430 valid questionnaires were finally obtained, with an effective rate of 87.07%. The sample data has a balanced proportion of males and females (n=210; 48.08% and ,220, 51.02% respectively). Students participated from King Saud University, aged from 18 to 21 years old. Inclusion criteria were as follows: 1) Students King Saud University, 2) aged from 18 to 21 years old, and 3) willing to participate in the study. Unwilling to participate in the study was the exclusion criterion. Overall, the sample structure is reasonably distributed and representative.

Ethical procedures

Participants were told that their answers would keep confidential and secret for the purpose of the research only. They were told also that they could withdraw at any time Written informed consent was obtained from the children's parents.

Measures

Survey

This research design compiled the "Investigation Scale on Factors Influencing Online Learners' Continuous Learning Willingness" and tested the validity of the scale through pilot testing. After reasonable modification of the scale through the analysis results of the test data, the scale has high reliability and validity and can be distributed and recycled on a wide scale. The final setting and reference basis of the scale items are shown in the table 1.

Table 1.
Measurement items and reference basis for latent variables

Latent variable	Coding	Items	Reference
Expect confirmation	EC1	I think the actual experience of using this online course was better than I expected	(Bhattacherjee, 2001)
	EC2	I think the gains and benefits of using this online course are better than I expected	
	EC3	I think the quality of the courses offered by this online course is better than I expected	
	EC4	Overall, the use of this online course basically met my expectations.	
Learning satisfaction	LS1	I found the learning experience using this online course to be enjoyable	(Çakmakkaya et al., 2024)
	LS2	I think using this online course has given me a sense of satisfaction	
	LS3	I think the learning effect of using this online course is satisfactory	
	LS4	Overall, I am satisfied with the process of using this online course	
Willingness to continue learning	CLI1	I plan to continue studying in this online course and not drop out	(Jiang et al, 2022)
	CLI2	I intend to stick with this online course and not use other alternatives	
	CLI3	I will recommend this online course to my classmates or friends.	
Perceived usefulness	PU1	Using this online course will improve my academic performance	(Davis et al., 1989)
	PU2	Using this online course can improve my learning efficiency	
	PU3	Using this online course has broadened my knowledge horizons	
	PU4	Overall, using this online course is valuable to my study and life	
Curiosity	CU1	I'm interested in discovering how things work	(Ho et al., 2021)
	CU2	When I encounter a difficult problem, I like to imagine the answer	
	CU3	When I get a complex thing, I like to ask others how it works	
	CU4	When I'm stumped by a puzzle, I'm interested in trying to solve it	
Attitude	AT1	I think it's a good idea to study in this online course	(Alharbi, 2023)
	AT2	I feel that studying in this online course is a wise choice	
	AT3	I would like to study in this online course	

Data analyses

This study uses SPSS 20.0 and AMOS 21.0 software to perform statistics and analysis on the collected sample data.

Common method deviation test

Generally, since the same scale is filled in by all subjects, subjects under the influence of the same background, the same environment, and the same measurement items will more or less have common method bias. The degree of common method bias depends on a certain extent, it will affect the survey results and even reduce the reliability of the researchers' research conclusions. Therefore, it is necessary to conduct a test for common method bias. This study used single-factor confirmatory factor analysis to test for common method deviation. After single-factor confirmatory factor analysis, it was found that the fitting degree was not ideal ($\chi 2/df=5.842$, RMSEA=0.133, CFI=0.835, GFI =0.648, NFI=0.809), indicating that the common method bias of the sample is not serious.

Results and Discussion

Measurement model testing

This study tested the reliability and validity of the measurement model respectively. As can be seen from Table 2, the Cronbach's α value, factor loading and combined reliability of each variable are all greater than 0.7, and the average variance improvement is greater than 0.5. This shows that the measurement model of this study has good reliability and convergence effect. Since the correlation coefficient of the latent variables in this study is large (>0.7), the Bootstrap method is used to test the discriminant validity of the

measurement model. The test standard is: calculate the confidence interval of the correlation number between each latent variable. If the correlation coefficient If the confidence interval does not include 1, it indicates good discriminant validity; otherwise, it indicates poor discriminant validity (Cheung et al., 2023).

As can be seen from Table 3 on the next page, the Bootstrap confidence intervals of the correlation coefficients between variables do not contain 1, indicating that the measurement model has good discriminant validity. Based on the above measurement results, the reliability and validity of the quantitative model in this study are good, and the structural equation model can be fitted.

Table 2.
Measurement model reliability and convergent validity test

Latent variable	Observed variables	Factor loadings	*p*	Cronbach's α coefficient	Composite reliability	Average variance extraction
Expect confirmation	EC1	0.905		0.888	0.893	0.805
	EC2	0.921				
	EC3	0.879				
	EC4	0.883				
Learning satisfaction	LS1	0.869		0.857	0.861	0.820
	LS2	0.925				
	LS3	0.952				
	LS4	0.935				
Willingness to continue learning	CLI1	0.816		0.863	0.886	0.723
	CLI2	0.868				
	CLI3	0.865				
Perceived usefulness	PU1	0.814		0.883	0.912	0.723
	PU2	0.787				
	PU3	0.891				
	PU4	0.903				
Curiosity	CU1	0.862		0.853	0.889	0.666
	CU2	0.809				
	CU3	0.774				
	CU4	0.818	***			
Attitude	AT1	0.934		0.843	0.851	0.827
	AT2	0.973				
	AT3	0.887				

Table 3.
Discriminant validity test of measurement model

Related variables	Correlation coefficient	Bootstrap confidence interval			
		Calibration Deviation	P	percentile	P
Expectation Confirmation <-->Learning satisfaction	0.856	[0.796,0.911]		[0.794,0.910]	
Expectation Confirmation<-->Perceived Usefulness	0.941	[0.888,0.984]		[0.888,0.983]	
Expectation Confirmation <-->willingness to continue learning	0.777	[0.676,0.854]		[0.683,0.860]	
Expectation Confirmation<-->Curiosity	0.755	[0.656,0.838]		[0.656,0.837]	
Expectation confirmation<-->attitude	0.793	[0.704,0.869]		[0.704,0.869]	
Learning satisfaction <--> Willingness to continue learning	0.895	[0.838,0.940]		[0.843,0.944]	
Learning Satisfaction<-->Perceived Usefulness	0.936	[0.884,0.976]		[0.884,0.976]	
Learning Satisfaction<-->Curiosity	0.702	[0.585,0.813]		[0.586,0.814]	**
Learning Satisfaction<-->Attitude	0.882	[0.835,0.926]		[0.834,0.924]	
Perceived usefulness <--> Willingness to continue learning	0.854	[0.777,0.917]		[0.780,0.918]	
Perceived usefulness<-->Curiosity	0.809	[0.717,0.877]	**	[0.717,0.877]	
Perceived usefulness<-->attitude	0.837	[0.754,0.902]		[0.754,0.902]	
Willingness to continue learning<-->Curiosity	0.748	[0.595,0.867]		[0.596,0.869]	
Willingness to continue learning<-->attitude	0.940	[0.889,0.979]		[0.891,0.983]	

Note: *p<0.05, **p<0.01, ***p<0.001.

Structural equation model fitting test and hypothesis verification

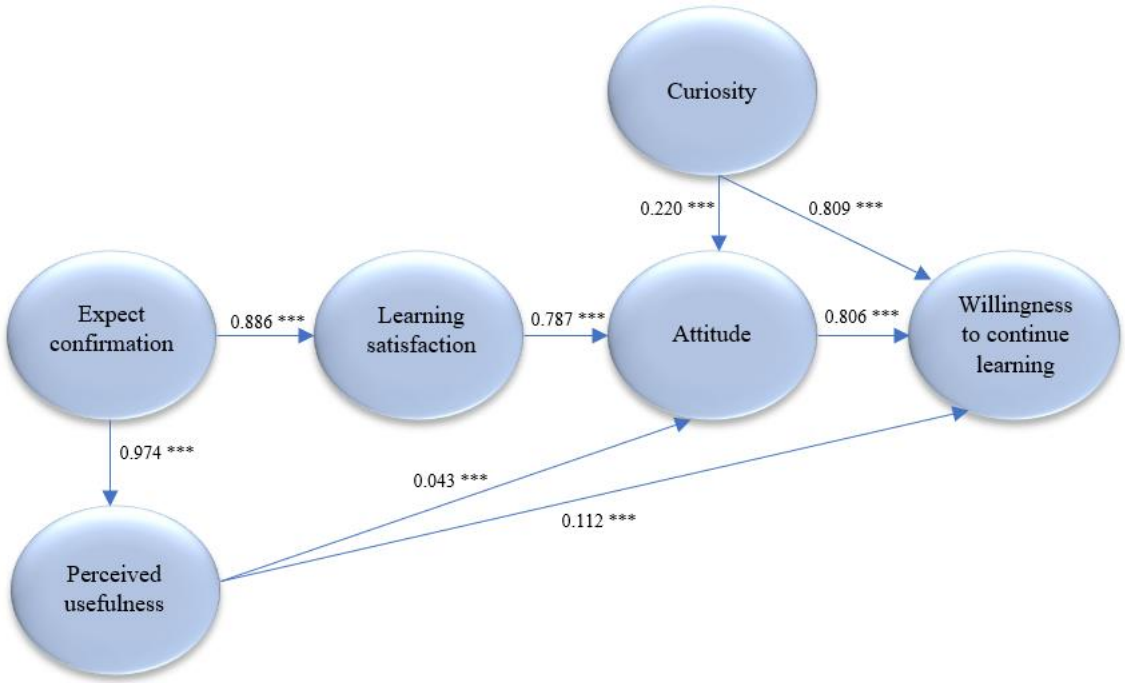
AMOS is used to test the fit of the theoretical model of factors influencing online learners' willingness to continue learning, and to evaluate the fit of the measurement model based on the parameter standards of

evaluation indicators such as CMIN/DF, RMSEA, SRMR, CFI, IFI, TLI, and GFI. The results are shown in Table 4. The results of the first model integration test showed that the parameter values of some evaluation indicators did not reach the standard reference values. Therefore, the MI correction index of the root structural equation model was modified to the original model. After the correction, each evaluation index of the model fit met its standard. Reference value, which shows that the overall fitting degree of the model is good, and this model can better explain the continuous learning intention of online learners.

Table 4.
Structural equation model fitting test results

Fit index	CMIN/DF	RMSEA	SRMR	CFI	IFI	TLI	GFI
Reference	<3.0	<0.08	<0.08	>0.90	>0.90	>0.90	>0.80
Actual value	3.444	0.099	0.249	0.913	0.914	0.900	0.812
Correction value	2.654	0.079	0.039	0.944	0.945	0.936	0.838

The verification of the research hypothesis is determined by the standardized path coefficients between potential variables and their significance. The numerical values of the standardized path coefficients are shown in Figure 3 on the next page. It can be seen from Figure 3 that there are positive correlations between expectation confirmation and learning satisfaction (β =0.899, p<0.001) and perceived usefulness (β =0.983, p<0.001). Hypotheses 1 and 2 are supported. Learning satisfaction (β=0.766, p< 0.001), curiosity (β=0.208, p<0.001) can positively predict attitude, hypothesis 5 and 7 are supported; the influence relationship between perceived usefulness and attitude is not significant (β=-0.040, p=0.684>0.05), hypothesis 4 is not supported. Attitude has a positive impact on willingness to continue learning (β =0.799, p<0.001), hypothesis 6 is supported. The relationship between curiosity and willingness to continue learning is not significant (β =0.082, p=0.206>0.05), perceived usefulness and willingness to continue learning. The relationship between them is not significant (β=0.107, p=0.148>0.05), and hypothesis 8 is not supported.



*Note: *p<0.05, **p<0.01, ***p<0.001*
Figure 3. Path coefficients of the modified model.

Table 5 shows the summary of results

Table 5.
Summary of results and hypotheses supporting

The results	Procedures	Status of Hypotheses
There are positive correlations between expectation confirmation and learning satisfaction and perceived usefulness	Standardized path coefficients	Hypotheses 1 and 2 are supported
Learning satisfaction, curiosity can positively predict attitude	Standardized path coefficients	Hypothesis 5 and 7 are supported
The influence relationship between perceived usefulness and attitude is not significant	Standardized path coefficients	Hypothesis 4 is not supported
Attitude has a positive impact on willingness to continue learning	Standardized path coefficients	Hypothesis 6 is supported
The relationship between curiosity and willingness to continue learning is not significant, perceived usefulness and willingness to continue learning. The relationship between them is not significant.	Standardized path coefficients	Hypothesis 8 is not supported

Starting from the perspective of ECM, this study introduced the two variables of attitude and curiosity on the basis of analyzing the rationality of the ECM structure, so that the research model can be expanded and better applied to related research in online or network learning environments. As indicated by the results, there is a positive correlation between expectation confirmation and learning satisfaction. Bhattacherjee (2001) found that expectancy performance could be an important determinant of satisfaction, because expectancy beliefs were the benchmarks that users used as reference judgments for assessing satisfaction. Cheng et al. (2016) proposed from the perspective of expectation value theory that student satisfaction depended on students' expectancy beliefs prior to learning. Appleton-Knapp & Krentler (2006) also proposed that when students' expectations were met, it was a positive predictor of satisfaction. Ye et al the expectancy value belief was positively related with theoretical course satisfaction.

There is a positive correlation between expectation confirmation and perceived usefulness. Satisfaction is affected by users' perceived usefulness and confirmation; perceived usefulness is affected by users' confirmation. However, some other studies found that perceived usefulness and satisfaction have significant effects on students' continuance intention while perceived usefulness has no significant effects on students' satisfaction (Daneji et al., 2019).

learning satisfaction and curiosity can positively predict attitude. von Stumm et al. (2011) have shown that students with an appreciable level of curiosity are more hard-working, well organized, and have the tendency to perform better academically. According to Cankaya et al. (2018), Gallagher & Lopez (2007), and Kashdan et al. (2009), curious students are likely to engage in unique and perplexing conditions in their daily routine and will meet and involve themselves more in prospects for progress and anticipated consequences.

Curiosity has an indirect impact on the willingness of online learners to continue learning. Just as curiosity is the driving force of learning, curiosity is also the driving force of online learners. With the support of a strong desire for knowledge, learners can maintain a positive attitude, which will generate a willingness to continue learning and enhance learning stickiness. Therefore, in terms of stimulating the curiosity of online learners to seek knowledge, it can be achieved through the setting of learning challenges. Learning challenges are reflected in the difficulty and novelty of online learning content and resources, the design of problem situations, the challenge of online learning tasks, and the establishment of an online interpersonal atmosphere.

Through learning challenges, online learners' desire to explore and the excitement of seeking knowledge about unknown things are stimulated, and learners are allowed to establish a positive coping attitude, thereby promoting their willingness to continue learning and the occurrence of continuous learning behaviors. It should be noted that excessive difficulty of learning challenges can easily lead to cognitive overload of online learners, thereby undermining learners' confidence and causing them to lose interest and curiosity in seeking knowledge. Therefore, the design of learning challenges should be based on the existing knowledge base and cognitive level of online learners, and should be suitable for the learners' "zone of proximal development" to stimulate learners' curiosity and enhance the continuity of learners' online learning.

Contrary to the results obtained by Nuryakin et al. (2023), the influence relationship between perceived

usefulness and attitude is not significant. The relationship between Perceived Usefulness, and attitude towards use is complex and may vary depending on the technology and the context in which it is used. Contrary to the results obtained by Deng (2021) who indicated that the study validates the role of curiosity as a multifaceted individual difference that serves as an antecedent to satisfaction with online education courses, the relationship between curiosity and willingness to continue learning is not significant. The relationship between perceived usefulness and willingness to continue learning is not significant. However, Huang (2021) obtained that PU positively affects students' continuous usage intention of online learning platforms. Roca & Gagné (2008) found that PU has the most significant effect on continuous intention and that some demographic variables existed.

Conclusion

Attention and research on online learners' willingness to continue learning are of great significance to the learning effects of online learners and even the sustainable development of online education. Although this study explores the influencing factors of online learners' willingness to continue learning from the perspective of ECM and draws corresponding conclusions, there are still limitations and room for further research: First, the number of effective samples available for research is not extensive enough. According to statistics, most of the effective samples are college students. The coverage of the sample is small and not representative of the general population. Future research will expand the categories of survey objects on the basis of ensuring a sufficient number of samples, and collect data on various types of online learners to increase the coverage and representativeness of the research sample. Second, willingness is an important predictor and explanation indicator of behavior. Research on online learners' willingness to continue learning is not the ultimate goal. To predict and explain online learning's continuous learning behavior based on online learners' willingness to continue learning is to test online learners continued learning behavior. The relationship between learning intention and continuous learning behavior will be an important direction for subsequent research.

Theoretical/practical implications and future research

The study analyzed the influencing factors and influencing mechanisms of online learners' willingness to continue learning and found that attitude is an important factor affecting online learners' willingness to continue learning, and supports learners to maintain positive attitude throughout the entire online learning process. It is an important help online learners to generate continuous learning intention and maintain learning behavior. The attitude of online learners is a direct factor affecting their willingness to continue learning. Starting from the factor of attitude, discussing how to keep online learners active and maintain a positive attitude is the key to their willingness to continue learning. Therefore, first, a good online teacher-student relationship is an important guarantee for learners to maintain positive academic emotions and form a positive learning attitude. Social interaction is an important means to effectively reduce social isolation in online learning communities, stabilize learners' emotions and moods, and maintain positive attitudes. Therefore, through the social interactive learning method of multi-person discussion and mutual assistance and collaboration in online learning communities, learners' loneliness in online learning can be reduced, and their sense of belonging in online learning can be enhanced so that they can maintain and maintain an attitude of active participation, thereby promoting learners' active learning, improving the continuity of learners' online learning, and enhancing their willingness to continue learning.

Curiosity, learning satisfaction, and expectation confirmation have an indirect impact on online learners' continuous learning intention, and attitude is the mediating factor for this indirect effect. Therefore, improving the degree of consistency between individual expectations and reality, maintaining individual desire for knowledge and exploration, and improving online learning satisfaction can have a certain impact on online learners' willingness to continue learning. Perceived usefulness has a certain impact on online learners' continuous learning. There is no significant impact on willingness, which means that although online courses can promote learners' progress in certain aspects, these advantages and characteristics cannot be sufficient conditions for online learners to generate continuous learning intention and maintain learning behavior.

Data availability statement Data will be made: available on request.

Declaration of competing interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Boosting math skills: The impact of game-based instruction on problem-solving in students with learning disabilities

تعزيز مهارات الرياضيات: تأثير التعليم القائم على الألعاب على حل المشكلات لدى الطلاب ذوي صعوبات التعلم

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Abstract

This study investigated the effect of game-based instruction on the learning of mathematical concepts and problem-solving skills in students with learning disabilities. The participants were 60 fourth-grade students identified with mathematical disabilities, divided into experimental (n=30) and control (n=30) groups. A semi-experimental pretest-posttest design with a control group was used. The experimental group received a 25-session intervention using game-based instruction. The results, analyzed using the paired-samples t-test, showed that the experimental group obtained significantly higher scores in the learning of mathematical concepts and problem-solving skills compared to the control group. This suggests that game-based instruction is an effective strategy for improving mathematical learning outcomes in students with learning disa-bilities.

Keywords: game –based instruction, learning math concept, problem-solving, students with learning disa-bilities.

الملخص

بحثت هذه الدراسة في تأثير التعليم القائم على الألعاب على تعلم المفاهيم الرياضية ومهارات حل المشكلات لدى الطلاب ذوي صعوبات التعلم. شارك في الدراسة 60 طالبًا من الصف الرابع الابتدائي ممن يعانون من صعوبات في الرياضيات، وقُسِّموا إلى مجموعتين تجريبية (العدد= 30 طالبًا) وضابطة (العدد=30 طالبًا). استُخدم تصميم شبه تجريبي ذي القياس القبلي والبعدي مع مجموعة ضابطة. تلقت المجموعة التجريبية تدخلًا تعليميًا قائمًا على الألعاب لمدة 25 جلسة. أظهرت النتائج، التي حُلِّلت باستخدام اختبار "ت" للعينات المقترنة، أن المجموعة التجريبية حققت درجات أعلى بكثير في تعلم المفاهيم الرياضية ومهارات حل المشكلات مقارنةً بالمجموعة الضابطة. وهذا يشير إلى أن التعليم القائم على الألعاب يُعد استراتيجية فعالة لتحسين نتائج تعلم الرياضيات لدى الطلاب ذوي صعوبات التعلم.

الكلمات المفتاحية: التعليم القائم على الألعاب، تعلم مفاهيم الرياضيات، حل المشكلات، الطلاب ذوو صعوبات التعلم

Introduction

Learning disabilities (LDs) are considered to be a general term for a series of heterogeneous cognitive dysfunctions. LDs are manifested in obvious difficulties in learning skills such as reading, mathematics, and writing. Individuals with learning disabilities have normal intelligence, but there is a large gap between their actual academic performance and the performance that can be achieved with their intellectual potential (Eissa & Mostafa, 2013; Elhoweris, 2017; Hoogendoorn, 2021; Ahmed Nassar, 2019). LDs usually include developmental learning disabilities and academic learning disabilities. The former include attention deficits, perceptual deficits, visual-motor coordination deficits, and memory deficits. The latter include reading disabilities, writing disabilities, and mathematics disabilities (Filiz & Güneş, 2022; Gomaa, 2016). LDs not only affect an individual's academic performance, but also have many negative effects on the individual's emotions, social interactions, and life in adulthood (Melekoglu et al., 2023; Zaien, 2021).

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Learning disability is a confusing condition because each person has a unique set of talents and characteristics. Students with learning disabilities are not blind, but they cannot see many things like their peers; they are not deaf, but in many cases they cannot hear or hear sounds like normal people. They are not cognitively delayed, but they learn in a different way (Gomaa, 2016).

Mathematics is one of the most complex human systems and one of the basic tools for learning (ElAdl, 2020; Koç & Korkmaz, 2020). Learning mathematics helps to enhance logical thinking and is also the foundation on which other areas of knowledge rely. However, the failure rate of mathematics learning is the highest, especially in the last stage of basic education (Koç & Korkmaz, 2020). In the process of learning mathematics, some students think that mathematics is a complex subject, so they lack interest in learning mathematics and suffer from poor mathematics performance. However, there are also some students who have normal intelligence but encounter more difficulties in the field of mathematics learning than other students. These students are children with mathematics learning disability (MLD) (Fatahalla, 2024)

Mathematics learning disability (MLD) is also called mathematical disability (MD), dyscalculia and developmental dyscalculia (Ikhwanudin & Suryadi, 2018). MLD refers to the phenomenon that students' mathematical learning performance lags behind that of children of the same age or grade due to the lack of ability or skills related to mathematical learning (Fatahalla, 2024). Before the 1970s, the research on learning disabilities (LD) mainly focused on dyslexia. It was not until the 1970s that mathematical disabilities received attention and concern

Therefore, mathematics is considered one of the basic sciences, and lack of interest in this subject leads to learning disabilities. Ultimately, it not only causes academic failure and waste of funds, but also leads to students' criticism and humiliation, the formation of a weak self-concept and a decrease in their self-esteem, and it also endangers their mental health. And it may lead them to unsuccessful defense mechanisms. These problems are carried from school and students to home and family, spreading anxiety and dissatisfaction in all areas of life, and the result of all this is severe damage to the mental health of society.

One of the methods used to expand and improve educational situations is the use of educational games (Aydın et al., 2024). The type of game is selected according to the needs of the students. It provides them with the opportunity to learn and practice these patterns through play (Sánchez Castillo et al., 2016). Playing strengthens students' social relationships, participation, trust, and a spirit of cooperation, development of learning processes such as observation, experiential learning, problem solving, and creativity in students, and most importantly, it makes learning enjoyable for students (Yang et al., 2021).

There are studies concerning game –based instruction in improving students' mathematics learning that have confirmed the effectiveness of this method (Debrenti, 2024). For example, results of Setyaningrum et al. (2018) indicated that the students who were exposed to the game-based learning within problem solving approach significantly outperformed their counterparts who were exposed on the basis of textbook within problem solving. Cayang & Ursabia (2024) affirmed that implementing game-based learning strategies in mathematics instruction is highly effective, resulting in a notable enhancement of learners' academic performance compared to conventional teaching methods. Additionally, the study of Munda et al. (2024) found statistically significant differences in the pre-test and post-test performances of their student subjects after applying the educational games.

The present study

The ability to count, understand unit by unit quantities, sort, subtract and compare numbers all depend on the experiences of objects. A child who has limited accuracy, insufficient perception and poor motor development may not have the desired experiences in activities related to manipulating and handling objects. Therefore, he will not be ready to achieve a real understanding of spatial relationships, shape, order, time, dimension and quantity. Game –based instruction can improve learning math concept and problem-solving in students with learning disabilities. There is a lack of experimental research to explore whether game –based instruction can improve learning math concept and problem-solving in students with learning disabilities.

Gaps and research Aims

Based on the lack of experimental research to explore whether game –based instruction and its effect on improving learning math concept and problem-solving in students with learning disabilities, this study clarifies the effect of game –based instruction learning math concept and problem-solving in students with learning disabilities, and summarizes the corresponding educational intervention strategies on this basis, in order to provide certain guidance and direction for front-line education and teaching work and future research.

Main hypothesis: Effect of training

As for our main hypothesis, it is predicted that students with learning disabilities who were trained in game –based instruction would increase earning math concept and problem-solving in posttest. Statistical analyses to test this hypothesis have been conducted with parametric tests.

Methodology

Research Design

A semi-experimental design with a pretest and posttest design with a control group was utilized by creating a game-based strategy (see figure 1).

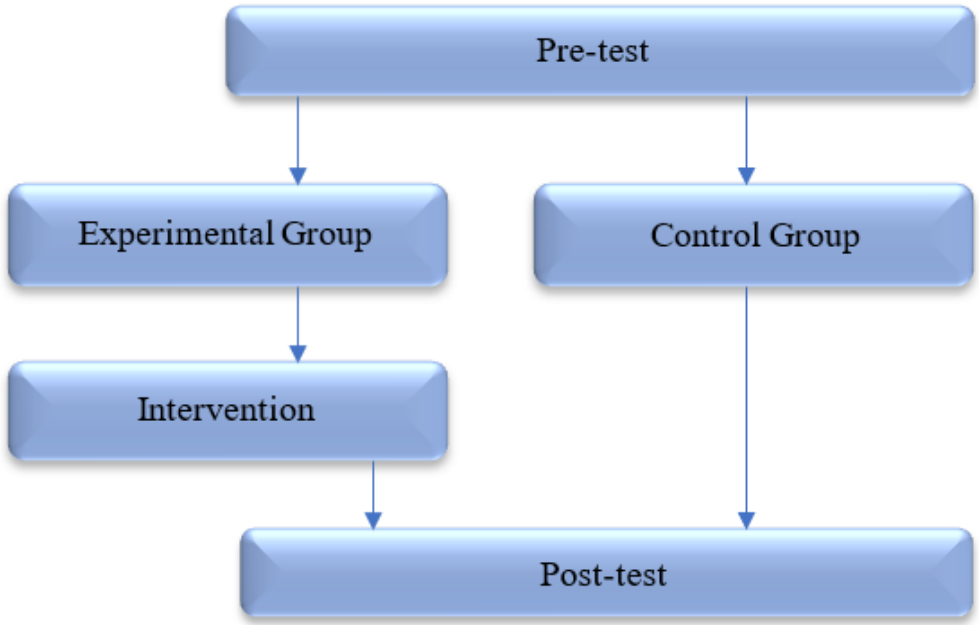

Figure 1. Research design.
(by the author)

Sample and Sampling Method

Children in the 4th grade from three primary schools in Taif city were selected to participate in the selection phase. With the help of schools Math teachers, Mathematics Academic Achievement Test was administered to the target students. The test scores were converted into standard Z scores according to grade, using performance below the 25th percentile (Andrade, 2021) as the cutoff score, selecting those whose with performance below the 25th percentile of the grade (standard score of 40 or scaled score of 5). Children were categorized as having mathematics learning disabilities if their performance on a standardized mathematics achievement test was below the 16th percentile (IQ < 80) or if their mathematical achievement was 1.5 standard deviations below their IQ score. Among the students, 60 were identified as children with math disabilities. The average age of the students upon entry to the study in the 4th grade was 9.94 years (SD = 0.88). To prevent the experimental results being affected by different instructors, the selected classes were taught by the same instructor. Parents were informed of the method of instruction that was used in the

treatment group of participating classrooms, but were blind to their student's placement in a treatment or control classroom. Randomization is the process of assigning participants to treatment and control groups (Peat, 2011), assuming that each participant has an equal chance of being assigned to any group, ensuring no a priori knowledge of group assignment (ie, allocation concealment). The sample was divided into two groups: experimental (n=30 students) and control (n=30 students)

Data collection

Mathematics concepts Test: This test was developed particularly for this study. It contains 15 questions under 3 dimensions: Geometry and Measuring (5 questions), Concept of Multiplication (5 questions), and Fractions (5 questions). In order to determine the reliability of the tests, 40 fourth grade elementary school students answered them at one-week intervals. The correlation coefficient between the scores obtained from the two equivalent tests was 0.79. Therefore, the **mathematics concepts test** has relatively good validity and reliability.

Mathematics Problem Solving Test: This test was developed particularly for this study. It contains 15 questions under 3 dimensions: Math Word Problems (5 questions), Addition and Subtraction Problems (5 questions), and Problem-solving Questions (5 questions). Time Sampling (Test-retest reliability). To determine whether the results of the test were stable over time, a study was completed in which raters completed the inventory twice, 3 weeks apart. The resulting coefficient was .89

Statistical Analysis

A Paired T-test was used to determine if there was a significant difference between math concept and problem-solving before and after utilizing the game-based strategy in terms of learners' scores.

Ethical Considerations

Gathered data were utilized to fulfill the study's purpose only. As such, the students' participated in the study voluntarily, and their agreement was sought through an informed consent form. All the data gathered were treated just for research purposes only and students were in complete anonymity.

Description of the educational training program

First session: Students got to know each other, formed groups of three, encouraged their cooperation in group activities, explained the duties of each member and each group, explained how to play the game and the purpose of playing the games in question. Second, third and fourth sessions: The selected activity of the second session was the game "Find and Write". In this game, each group was given a basket with several balls on which a mathematical exercise (single-digit addition or subtraction) was written. One of the group members picked up a ball and then, with cooperation and common thinking, they solved the exercise on it in the activity notebook. In the third session, two-digit addition or subtraction was done, and in the fourth session, three-digit addition and subtraction.

Fifth, sixth and seventh sessions: In the fifth session, the game "Accuracy" was selected as an activity. In this game, students used cubes with different numbers written on them to arrange the addition or subtraction (single-digit) expressions with the answer, and one of the group members wrote it in the activity notebook.

In the sixth session, the exercise (two-digit) was written on the board and the group members arranged the cubes according to it. In the seventh session (advanced stage), each student did one- or two-digit exercises individually. Eighth, ninth, and tenth sessions: The optional activity of the eighth session was the "number pantomime" game. In this game, one of the students showed one-digit, two-digit, or three-digit numbers with the help of the fingers of both hands, and the other students stated the desired number and wrote it on the sheet. In the ninth session, one of the mathematical functions (addition or subtraction) was shown in the form of a pantomime. The students consulted with each other in the group and answered in cooperation. In the tenth session (the advanced stage of this activity), the exercise was done individually.

The eleventh, twelfth, and thirteenth sessions: In the eleventh session, the goal was to learn problem-solving skills, and the optional activity for this session was "role-playing," which was performed through a play. In

this game, a group consulted together and performed a play related to daily shopping that represented a mathematical problem, such as: buying several types of stationery that required adding up their prices.

Other students in the group consulted with each other and answered the problem first orally and then on paper. At first, the price of stationery and other items was a single digit, but in the next session, two-digit and three-digit numbers were considered. This activity was also answered individually in the thirteenth session. The fourteenth, fifteenth, and sixteenth sessions: The goal was to examine and strengthen visual abilities. The desired activity was "pattern finding," which was performed in groups according to the color of the layers. In the fifteenth session, pattern-finding was done based on geometric shapes and in the sixteenth session, based on numbers.

The seventeenth, eighteenth, and nineteenth sessions: The goal was to strengthen auditory memory and the activity was "Let's be together." In the seventeenth session, each student was given a number. The students had to come to the front of the class according to the addition or subtraction (single digit) written on the board and their number. The student who had the number corresponding to the answer solved the exercise with the help of friends. In the eighteenth session, the same activity was done, but with two-digit addition and subtraction and group consultation. In the nineteenth session, both types of exercises were written individually.

The twentieth, twenty-first, and twenty-second sessions: Increasing problem-solving skills. The goal of these sessions and the related game was "Magic Ball." Accordingly, before the session, the addition or subtraction (single digit) was written on the balls in the basket. One person from each group took a ball from the basket, then with the help of friends, they told a short story. In the twenty-first session, the same procedure was followed, but with the solution written in the activity notebook. In the twenty-second session, addition and subtraction with two-digit numbers were done.

In the twenty-third, twenty-fourth, and twenty-fifth sessions: In order to increase the accuracy and concentration of the students, the game "Matching Familiar Shapes" was considered. In this game, several cards with a number of shapes related to different shapes (such as leaves, trees, and animals) that had slight differences from each other were provided to the groups. Group members had to choose a shape from the given shapes. The next session was the “Maze-Finding” game. Two similar pictures with a few minor differences were provided to the groups so that they could find the differences with each other. In the next session, a picture containing a number of hidden animal pictures was provided to the students. The students first had to find the hidden pictures accurately, then color them.

Results and discussion

To test hypotheses, mean and standard deviation of Mathematics concepts Test and Mathematics Problem Solving Test scores in the pre- and post-tests for each group. As shown in Table 1, differences existed between the mean scores of the experimental and control groups in the pre-test and post-test. Children in experimental group had higher scores in all Mathematics concepts Test subscales than did those in the control group, and in Mathematics Problem Solving Test, children in experimental group had higher scores in all subscales than did those in the control group (See table 1).

After that, the covariance analysis test was used to determine how significant were the differences, as shown in Table 2. After controlling for the pre-test effect, there was a significant difference between the pre-test and post-test scores of children in the experimental group in the subscales of executive functions and theory of mind (ToM) skills ($P \leq 0.05$).

Table 1.
Mean and standard deviation of Mathematics concepts Test and Mathematics Problem Solving Test scores in the pre- and post-tests for each group

Variables	Mean ± SD
Mathematics concepts Test	
Geometry and Measuring	
Experimental	
Pretest	2.15 ± 0.863
Posttest	4.66 ± 0.272
Control	
Pretest	2.17 ± 1.001
Posttest	2.23 ± 1.144
Concept of Multiplication	
Experimental	
Pretest	2.11 ± 0.663
Posttest	4.48 ± 0.411
Control	
Pretest	2.15 ± 0.842
Posttest	2.19 ± 2.115
Fractions	
Experimental	
Pretest	2.18± 0.449
Posttest	4.62 ± 0.623
Control	
Pretest	2.16± 0.744
Posttest	2.35± 0.981
Mathematics Problem Solving Test	
Math Word Problems	
Experimental	
Pretest	2.15 ± 1.221
Posttest	4.56 ± 0.446
Control	
Pretest	2.20 ± 1.310
Posttest	2.21± 0.865
Addition and Subtraction Problems	
Experimental	
Pretest	2.10 ± 1.000
Posttest	4.70 ± 0.433
Control	
Pretest	2.12 ± 1.001
Posttest	2.19± 0.681
Problem-solving Questions	
Experimental	
Pretest	2.17 ± 1.116
Posttest	4.88 ± 0.835
Control	
Pretest	2.16 ± 0.879
Posttest	2.18± 0.736

(By the author)

Table 2.
Covariance Analysis test Results for Comparing theory of mind (ToM) skills of Children in the Control and Experimental Groups

Source of Change	Sum of the Squares	Df	Mean Squares	F	P-Values	Effect Size
Mathematics concepts Test						
Pretest	2.20	1	2.20	12.4	0.001	0.39
Group	4.67	1	4.67	68.3	0.001	0.88
Mathematics Problem Solving Test						
Pretest	2.17	1	2.17	10.7	0.001	0.40
Group	4.69	1	4.69	69.4	0.001	0.89

Note.: ETA Square ranged from 0.45 to 0.87 for all variables respectively. High size effect (Cohen, 1988 suggested that =0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size).
(By the author)

Discussion

The results of the present study showed that the experimental group that underwent the experimental game –based intervention obtained higher scores in learning mathematical concepts and problem-solving ability compared to the control group. In this study, the first hypothesis was that game –based instruction is effective in promoting students' learning of mathematical concepts. The results of the experiment and data analysis showed that this hypothesis was supported and game –based instruction improved students' learning of mathematical concepts, and the mean scores of the variable learning of mathematical concepts of the experimental group subjects in the post-test situation increased significantly compared to the control group. Therefore, it can be said that game –based instruction was effective in improving students' learning of mathematical concepts.

Game-based Learning and Mathematics

These results are supported by other studies in the literature. For example, a study by Lin et al. (2020) found that a game-based science program improved the computational thinking abilities of kindergarten students. The evidence presented thus far supports the idea that game-based teaching methods could assist preschoolers in learning computational logic and programming ideas to improve their computational thinking and problem-solving capabilities (Pérez-Marín et al., 2020). A study by Xu et al. (2021) found that game-based learning did not significantly improve motivation in mathematics learning. Game-based learning using different game application tools emphasizes the importance of strengthening the foundation of math concepts and the mathematical proficiency to solve various problems in math. According to Orbon & Sapin (2022), using game-based learning in teaching influences the development of students' positive attitudes toward mathematics as the most challenging subject and boosts their motivation, accelerated acquisition, and longterm memory.

Thus, by playing games, discipline and accuracy in paying attention to the surroundings, discipline and accuracy in listening, discipline and accuracy in seeing, in speech and behavior, responsibilities, decision-making, discipline and accuracy in the ability to solve everyday problems are strengthened. In addition, he believes that the result of intellectual and physical preparation and activities carried out by students is solving problems and achieving peace and mental balance, all of which It produces effects and results that will lay the groundwork and determine how students will deal with problems, their attitudes, activities, and decisions in the future.

Children who are unable to learn mathematics have a delayed or interrupted development of normal attention and precision. Children with learning disabilities in mathematics, although they know mathematical operations well, make mistakes due to insufficient attention. Some believe that teachers should establish direct personal relationships with their students and consider their needs, abilities, and talents in arranging learning activities (Pérez-Marín et al., 2020). Above all, learning should be satisfying and self-directed. Students can use all their learning capacities when they enter the learning environment with interest and enthusiasm and love learning.

These results indicate that game –based intervention is an approach in which the teacher selects a specific tool according to the type of child's problem (Yeratziotis et al., 2024). The type of game is selected according to the needs of the students and, with his active participation while playing, he considers the new patterns needed by the students and provides them with the opportunity to learn and practice these patterns through the game (Adipat et al., 2021). In games, students' social relationships, participation, trust, and a spirit of cooperation are strengthened. Games promote the development of learning processes such as observation, experiential learning, problem solving, and creativity in students. It reinforces and, most importantly, makes learning enjoyable for students (Alotaibi, 2024).

Educational implications

Children must master a series of skills to learn mathematical tasks. The acquisition of these skills is through experience, training, and learning. Most children perform these skills automatically, but children with learning disabilities in mathematics have difficulty learning these skills and need to be given special training. Children gain their experiences in various ways, including games, during their growth period. Therefore, if teachers take steps to enrich the educational environment and design purposeful games, they will be effective to some extent in the development and improvement of children's learning. By using

purposeful, diverse, and attractive games in line with the goals of the mathematics lesson, in addition to making students with learning disabilities interested, learning mathematical concepts and problem-solving skills can also be improved so that they can use their knowledge in daily life and have sufficient accuracy and concentration in carrying out life's tasks.

Limitations

This study had limitations. Among them, it can be noted that the sample group was limited to the city of Taif and the research population, which was limited to boys. Therefore, it is better to proceed with caution when generalizing the results of this study to other geographical areas. It is also suggested that other researchers, using more efficient human resources and appropriate material resources, consider a larger statistical population and select the sample group from both female and male students. They can also examine the effect of other variables such as reading and painting on learning mathematical concepts and problem solving.

Conclusion

Learning mathematics is a social process, through which students build their mathematical knowledge and skills by collaborating with each other and in groups, and learning opportunities arise through group discussion, explanation, justification, and discussion about meaning and concept (Erath, 2021). Research has shown that children with learning disabilities are weaker than normal children in learning mathematical concepts (Landerl et al., 2009). The use of purposeful games to improve the cognitive skills of individuals with learning disabilities arises from the advancement of knowledge in the field of plasticity and self-healing capacity of the human brain, which has strong evidence that neuropsychological functions such as attention and concentration can be improved with the help of cognitive training (O'Connell et al., 2007; Zhong (2019) and by increasing the accuracy and concentration of students, the learning rate of mathematical concepts and problem-solving ability can also be improved.

Practical implications

Game-based learning transforms the educational paradigm from a teacher centered approach to one where learners actively participate in teamwork to grasp new concepts. Implementing game-based learning strategies in mathematics instruction is highly effective, resulting in a notable enhancement of learners' academic performance.

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Plants discovered in Costa Rica between 2010 and 2020 and their possible pharmacological use

Plantas descubiertas en Costa Rica entre 2010 y 2020 y su posible utilidad farmacológica

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Abstract

Costa Rica is known for having 6% of the world's biodiversity, approximately 12% of the plant species that exist in the country are endemic and because in Costa Rica the use of plants for medicinal purposes has been a tradition, it is important to know the potential pharmacological activities of the species that have recently been discovered. A bibliographic search was carried out under the criteria: Costa Rican species, endemic, recently discovered (2010-2020), that have few studies, that present ethnobotanical uses or that the family to which they belong, report this type of medicinal use. One or more criteria had to be met and, therefore, information on plants from 18 families is reported. Finally, it is very important to carry out more research on the large number of plant species that have been discovered in Costa Rica since it could be useful to know the molecular and phytochemical profile of these species both to know if they have pharmacological potential, as well as to know better its taxonomic and evolutionary classification.

Keywords: Costa Rica, endemic, ethnobotanical, medicinal uses, new species.

Resumen

Costa Rica es conocida por tener el 6% de la biodiversidad mundial, aproximadamente el 12% de las especies vegetales que existen en el país son endémicas y debido a que en Costa Rica el uso de plantas con fines medicinales ha sido una tradición, es importante conocer las potenciales actividades farmacológicas de las especies que se han descubierto recientemente. Se realizó una búsqueda bibliográfica bajo los criterios: especies costarricenses, endémicas, descubiertas recientemente (2010-2020), que tengan pocos estudios, que presenten usos etnobotánicos o que la familia a la que pertenecen, reporte este tipo de uso medicinal. Se debía cumplir uno o más criterios y, por lo tanto, se reporta información sobre plantas de 18 familias. Por último, es muy importante realizar más investigaciones sobre la gran cantidad de especies vegetales que se han descubierto en Costa Rica ya que podría ser útil conocer el perfil molecular y fitoquímico de estas especies tanto para saber si tienen potencial farmacológico, así como para conocer mejor su clasificación taxonómica y evolutiva.

Palabras clave: Costa Rica, endémica, etnobotánica, usos medicinales, nueva especie.

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Introduction

Costa Rica is recognized for being one of the 20 countries with the greatest diversity of species in the world and possibly the country with the highest density. It is estimated that around 500 000 species can be found in Costa Rica, representing 6% of the world's biodiversity, of which, until 2018, more than 121 000 are known, for an estimated 2.3 species per Km (Aguilar Sandí, 2018; Ministerio de Ambiente y Energía (MINAE) et al., 2018).

The number of plant species in the country is estimated at more than 11 500 (Aguilar Sandí, 2018).

Approximately 12% of these are endemic (Ministerio de Ambiente y Energía (MINAE), 2018). Therefore, they are known only in Costa Rica and it is not possible to find them naturally in any other country (Acebey Dávalos et al., 2012). About 500 species of medicinal plants are included from these (Ulloa Leitón, 2017).

Since ancient times, plants have been used for medicinal purposes, in Costa Rica this tradition has had the contribution of knowledge of the indigenous, Spanish, and Afro-Caribbean people (Museo de Cultura Popular, 2024). The usefulness of these plants has been transmitted from generation to generation orally or in a written manner (García-González & Morales, 2005). Nevertheless, popular knowledge about the use of medicinal plants has recently been lost substantially (Contreras Arias & Campregher, 2010).

In some cases, the effects of plants in the treatment of certain diseases have resulted in the overestimation of the possible effects of certain plants, attributing properties that they do not possess. Currently, interest in medicinal plants is increasing globally, and Costa Rica is not the exception, either because of the need to reduce drug use and the side effects they generate or because people do not have the economic resources to access health services or treatments (García-González & Morales, 2005).

This carries into an increase in global consumption and trade in medicinal plants and herbal products; furthermore, it represents a fantastic opportunity for the country. The state has encouraged sustainable and cost-effective production of such plants, both for export and for domestic consumption. This growth in demand could bring improvements in regulations, production practices, quality, safety and efficiency of plants and their preparations (Ulloa Leitón, 2017).

Medicinal plants are particularly important in the pharmacological research and development of new medicines, they can be used as therapeutic agents or for obtaining useful pipelines in the synthesis of medicines. Although very few species have been studied in terms of their possible applications in medicine, there is very little information on the efficacy and safety of these plants, their active components, extracts, and preparations containing them, so the World Health Organization has urged member countries to regulate trade of these products (World Health Organization, 2000).

Considering the above and the growing number of plants discovered in the country, it becomes imperative to collect the most recent discoveries reported in the literature and identify possible medicinal uses of these new species.

Methodology

The present study was carried out as a bibliographic review aimed at collecting information on plant species recently discovered in Costa Rica between 2010 and 2020 (Fig 1). The objective was to identify endemic species with possible pharmacological use, considering specific inclusion criteria based on ethnobotanical and medicinal background.

For the selection of the species, the following inclusion criteria were established: (1) be Costa Rican and endemic species, (2) have been discovered between 2010 and 2020, (3) have few previous studies, (4) present documented ethnobotanical uses, and (5) belong to families with a history of reported medicinal uses. A species had to meet at least one of these criteria to be included in the analysis.

The bibliographic search was carried out in scientific databases such as PubMed, Scopus, Medline, Google Scholar and Elsevier, as well as in articles, books and resources available in the library system of the University of Costa Rica. Keywords used in the search included combinations of terms such as: “Costa Rican species,” “endemic,” “recently discovered (2010-2020),” “ethnobotanical uses,” “medicinal uses,”

and "new species." These keywords were used in both English and Spanish to expand the coverage of relevant information.

The procedure consisted of performing initial searches with the keywords mentioned, followed by filtering the results to exclude duplicates and irrelevant references. The selected documents were analyzed to identify information on taxonomy, geographic distribution, and possible medicinal applications of the species. The data collected were organized by botanical family and distribution region.

The information extracted was validated by peer review, which guaranteed the quality and accuracy of the data used. The findings were presented in tables and figures to illustrate relevant patterns, such as the temporal and geographic distribution of the discovered species.

Results and Discussion

In this study, a total of 46 species were analyzed and identified (Table I), distributed across different parts of the country (Fig. 2), all meeting one or more of the inclusion criteria established for the research. The findings highlight the limited research conducted on these species, emphasizing the need for further study, particularly at the molecular level. Notably, these species belong to major families with documented medicinal applications, as detailed below:

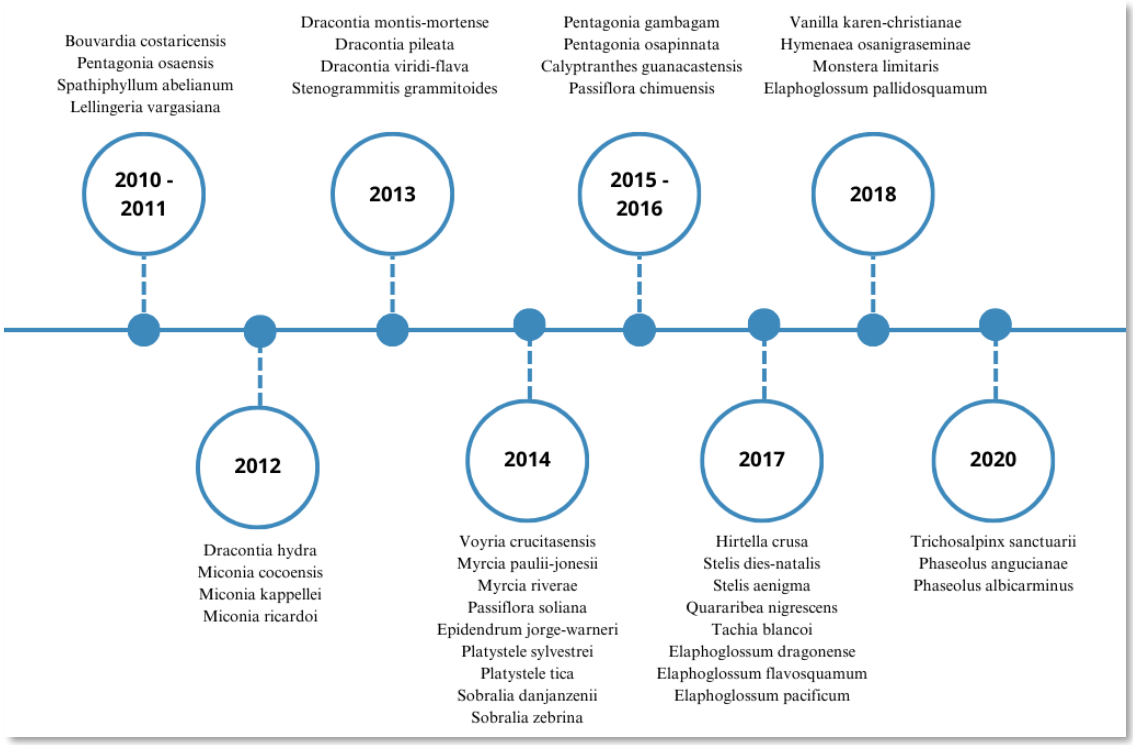

Fig. 1. Temporal distribution of the different newly discovered species (2010-2020), after an exhaustive review of original articles, both in English and Spanish, focused on endemic Costa Rican species.

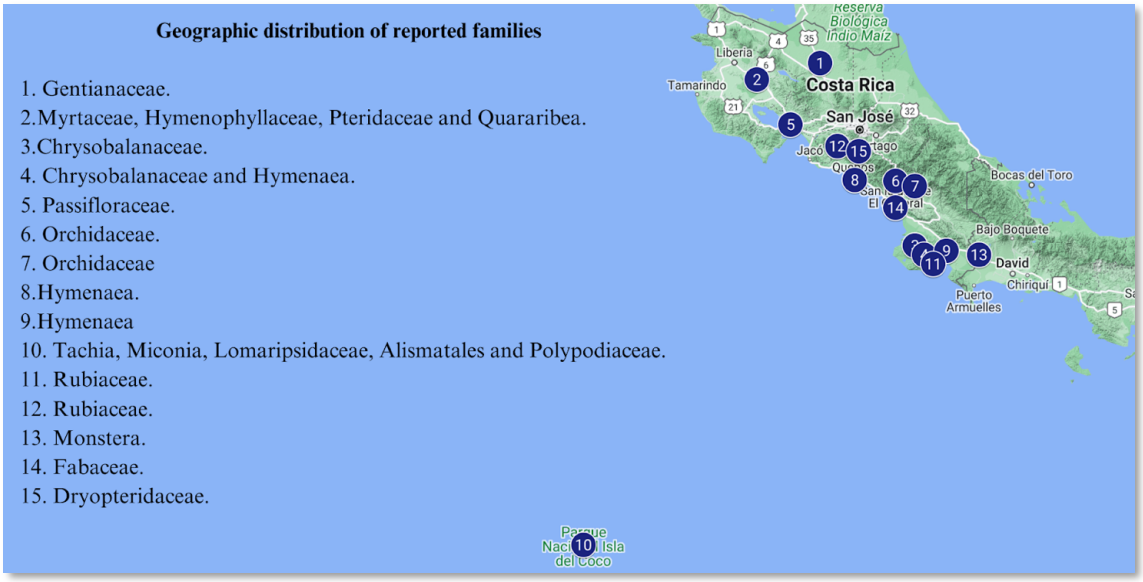

Fig 2. Distribution of the different families after an exhaustive review of original articles, both in English and Spanish, focused on Costa Rican endemic species.

Table I.

Comprehensive review of original articles, both in English and Spanish, focused on endemic species of Costa Rica, recently discovered (2010-2020), with limited studies, with ethnobotanical uses of the families with reported medicinal uses.

Plant Family	Plant Species	Taxonomic classification	Distribution	Study report Family
Gentianaceae:	***Voyria crucitasensis*** Y. Guillén & G. Vargas, sp.nov.	Plantae, Spermatophyta, Magnoliopsida, Gentianales, Gentianaceae, Voyria (Guillén Rodríguez & Vargas Rojas, 2014).	Species endemic to Costa Rica, collected in the very humid tropical forest of the Caribbean slope, Crucitas de Cutris, lajuela (Guillén Rodríguez & Vargas Rojas, 2014).	It has been reported that species from this family, such as *Eustoma* Salisb. and *Exacum* L., have ornamental value. Other species, such as *Gentiana* L. and *Swertia* L., are used in traditional Mexican medicine or as sources of pharmacologically and cosmetically relevant compounds (Rostro del Muro et al., 2024). In Mexico, the Otomí people use *Gentiana spathacea* Kunth and *Gyrandra tenuifolia* to treat gastrointestinal disorders (Rostro del Muro et al., 2024). *Gentianella* (*G. nitida* Griseb., *G. alborosea* (Gilg) Fabris), commercially known as "hercampure" or "hercampuri" in traditional medicine, contain bitter compounds and are recommended for the treatment of flu, diabetes, high cholesterol, obesity, liver disorders, blood detoxification, stomach pain, gastritis, skin conditions (such as acne), postpartum pain, arthritis, and rheumatism, as well as for appetite stimulation (Seminario et al., 2021). It has been identified that the vast majority of these species contain polyphenols, xanthones, pectins, saponins, triterpenes, sesquiterpenoids, sterols, and other bioactive compounds (Seminario et al., 2021).
Myrtaceae	***Calyptranthes guanacastensis*** N. Zamora, S. Kim, & R. Espinoza, sp.nov	Plantae, Spermatophyta, Magnoliopsida, Myrtales, Myrtaceae, Calyptranthes (Zamora et al., 2016).	Endemic species of the northwest region of Cordillera de Guanacaste, Costa Rica (Zamora et al., 2016).	The use of species belonging to the family Myrtaceae has been reported in the treatment of influenza and cough (Eucalyptus globulus and Eucalyptus citriodora), abdominal pains (Pimenta ozua) ,as an antiemetic (Pimenta dioica), to treat toothache (Pimenta racemosa and Syzygium aromaticum) and rheumatism (Pimenta racemosa), to calm nerve crises, diarrhea, vomiting, abuse of alcoholic beverages, and to treat rashes (Psidium guajava) (Germosén-Robineau, 2014). The Myrtaceae family is well known among the Brazilian population, which justifies its use as an astringent, anti-inflammatory, and antihypertensive agent, as well as for treating gastrointestinal disorders. The main bioactive constituents of these species include carotenoids, phenolic compounds, monoterpenes, and sesquiterpenes (Antonelo et al., 2023).
	Myrcia paulii-jonesii Aguilar, D. Santam., & A. Estrada, sp.nov.	Plantae, Spermatophyta, Magnoliopsida, Myrtales, Myrtaceae, Myrcia (Santamaría-Aguilar et al., 2014).	Endemic species of Costa Rica, found in the surroundings of Bahía Chal, Osa Peninsula (Santamaría-Aguilar et al., 2014).	
	Myrcia riverae A. Estrada, D. Santam., & Aguilar, sp.nov.	Plantae, Spermatophyta, Magnoliopsida, Myrtales, Myrtaceae, Myrcia (Santamaría-Aguilar et al., 2014).	Endemic species of Costa Rica, found in Golfo Dulce and Península de Osa (Santamaría-Aguilar et al., 2014).	
Chrysobalanaceae	***Hirtella crusa*** Aguilar & D. Santam., sp.nov.	Plantae, Spermatophyta, Magnoliopsida, Violales, Passifloraceae, Passiflora (Estrada-Chavarría & Rivera, 2014).	Species endemic to Costa Rica (Estrada-Chavarría & Rivera, 2014).	Passiflora edulis Sims leaves contain a glycoside called passiflorine, which has calming and sedative properties. In Las Guayanas, an infusion of these mixed with Ricinus communis is used to treat liver inflammation. Infusions from the Passiflora foetida L. plant for the expulsion of intestinal parasites. It is also used to fight cases of flu, cold and tuberculosis. Infusion of the leaves of this plant is used to treat stomach conditions (González, 2013). Passiflora quadrangularis L. roots have emetic, diuretic and verfuge properties (expel intestinal parasites) and can be used to treat skin conditions. The pulp of the fruits contains passiflorine. Moreover, it has been used to fight asthma, diarrhea, headache, dysentery, scurvy, insomnia, and neurasthenia (González, 2013). Likewise, larvae of the butterfly Philethria dido have been seen eating from its leaves (Estrada et al., 2016).
	Passiflora chimuensis A. Estrada, G. Rivera, J. Solano., sp.nov.	Plantae, Passifloraceae, Passiflora L., Astrophea, Pseudoastrophea (*Passiflora chimuensis*) (Estrada et al., 2016).	Endemic to Costa Rica, in very humid forests of the Caribbean, in the foothills of the Central Volcanic Range and Talamanca, at an elevation between 340 and 770m (Estrada et al., 2016)	
Orchidaceae	***Dracontia montis-mortense*** Karremans & Bogarín, sp.nov.	Plantae, Tracheophyta, Liliopsida, Asparagales, Orchidaceae, Stelis (Karremans & Bogarín, 2013)	Species endemic to Costa Rica, in the area known as Cerro de la Muerte (Karremans & Bogarín, 2013).	Some genera of this amily, such as Calanthe, Phaius, Acanthephippium, and Tainia, are medicinally important due to their rich content of starch and alkaloids (Zhou et al., 2023) Rhynchostylis retusa (L.) Blume is traditionally used for the treatment of pain, inflammation, and skin diseases. Traditionally, the whole plant is used to treat

	Dracontia pileata Karremans & Bogarín, sp.nov.	Plantae, Angiospermae, Liliopsida, Orchidales, Orchidaceae, Stelis (Karremans & Bogarín, 2013)	Species endemic to Costa Rica, found in the surroundings of San Isidro del General and on the Pacific side of the Cordillera de Talamanca (Karremans & Bogarín, 2013).	dysentery, gout, asthma, rheumatic pain, tuberculosis, epilepsy, menstrual disorders, skin diseases, and inflammation. The aerial roots are used to treat inflammation, pain, and malarial fever (Al-Amin et al., 2023). Some species of the Orchidaceae family are widely used in traditional medicine for the treatment of various diseases, including cancer and inflammation (Qi et al., 2021). On the other hand, literature on medicinal plants of the Orchidaceae family describes them as rich in dihydrophenanthrenes (DPs), flavonoids, triterpenoids, alkaloids, and bibenzyls, among other secondary compounds. Modern pharmacological studies have shown that DPs in medicinal plants of the Orchidaceae family exhibit anti-inflammatory, antitumor, antioxidant, and antibacterial activities (Qi et al., 2021).
	Dracontia hydra Karremans & C.M.Sm., sp.nov. C.M. Sm	Plantae, Angiospermae, Lilidae, Orchidales, Orchidaceae, Stelis (Karremans & Smith, 2012).	Species endemic to Costa Rica, only in Cerro Urán and Cerro Buena Vista (Karremans & Díaz-Morales, 2017).	
	Stelis aenigma Karremans & M.Díaz, sp.nov.	Plantae, Equisetopsida, Asparagales, Orchidaceae, Stelis (Karremans & Díaz-Morales, 2017).	Species endemic to Costa Rica, only known in Cerro Arbolado and Cerro Utyum, Cordillera de Talamanca (Karremans & Díaz-Morales, 2017).	
	Epidendrum jorge-warneri Karremans & Hágsater, sp. nov.	Plantae, Tracheophyta, Liliopsida, Asparagales, Orchidaceae, Epidendrum L (Fernández et al., 2014).	It is only known in Costa Rica, only found on the Tinuk hill and grows in an isolated part of moor about 2400m high (Fernández et al., 2014).	
	Platystele sylvestrei Karremans & Hágsater, sp. nov.	Plantae, Tracheophyta, Liliopsida, Asparagales, Orchidaceae, Platystele Schltr. (*Platystele sylvestrei*) (Fernández et al., 2014).	Known only in Costa Rica and Panama. In Costa Rica it grows in mature wet premontane forest, between 1410 and 1650m tall. It is in the Tapantí National Park in Cartago, near San Ramón de Alajuela, in the Monteverde area of Puntarenas and on the border between Costa Rica and Panama) (Fernández et al., 2014).	
	Platystele tica Karremans & Bogarín, sp. nov.	Plantae, Tracheophyta, Liliopsida, Asparagales, Orchidaceae, Platystele Schltr. (*Platystele sylvestrei*) (Fernández et al., 2014).	Known only in Costa Rica in the South Pacific area and in the El General Valley, it may be present in southern Colombia. Epiphytic plant in the premontane secondary forest humid at an altitude of 300 and 450 m (Fernández et al., 2014).	
	Sobralia danjanzenii Dressler & Pupulin, sp.nov.	Plantae, Angiospermae, Lilidae, Orchidales, Orchidaceae, Sobralia (Dressler & Pupulin, 2014)	Species endemic to Costa Rica, found from the Guanacaste mountain range to the Cerros de Turrubares, south of San José (Dressler & Pupulin, 2014). Utility: No medicinal uses have been reported for this species.	
	Sobralia zebrina Dressler & Pupulin, sp.nov.	Plantae, Angiospermae, Lilidae, Orchidales, Orchidaceae, Sobralia (Dressler & Pupulin, 2014)	Species endemic to Costa Rica, found in the northern part of the Talamanca mountain range (Dressler & Pupulin, 2014).	
	Trichosalpinx sanctuarii Mel. Fernández & Bogarín, sp.nov.	Plantae, Angiospermae, Lilidae, Orchidales, Orchidaceae, Trichosalpinx (Fernández & Bogarín, 2013).	Species endemic to Costa Rica (Fernández & Bogarín, 2013).	
	Vanilla karen-christianae Karremans & P. Lehm., sp. nov.	Plantae, Equisetopsida, Asparagales, Orchidaceae, Vanilla (Karremans & Lehmann Calderón, 2018).	Species endemic to Costa Rica, Known only in the vicinity of the border with Panama, Corredores de Puntarenas (Karremans & Lehmann Calderón, 2018).	
Quararibea	***Quararibea nigrescens*** N. Zamora, Cascante & S.Y. Kim., sp.nov.	Plantae, Magnoliophyta, Magnoliopsida, Malvaceae, Quararibea. (Quararibea nigrescens) (Zamora et al., 2017).	It is endemic to Costa Rica, found on the Caribbean slope of the Cordillera de Guanacaste, Cordillera de Tilarán and Cordillera Volcanic Central, between 400 and 1100 meters above sea level (Zamora et al., 2017)	Genera such as *Quararibea cordata* have antioxidant potential associated with immune system enhancement (Berto et al., 2015). According to the literature, this family contains bioactive metabolites effective against dysentery, stomach discomfort, fever, enteritis, hepatitis, cough, sore throat, arthritis, and diabetes. Notable metabolites include flavonoids, saponins, terpenoids, phenols, and tannins (Zafar et al., 2023).

Hymenaea	***Hymenaea osanigraseminae*** Aguilar, Poveda, D. Santam., sp.nov.	Plantae, Leguminosae, Hymenaea. (Hymenaea osanigraseminae) (Aguilar Fernández et al., 2018).	It is known only in Costa Rica in the Central Pacific, in the Manuel Antonio National Park and in the South Pacific in Golfito and in the Osa Peninsula. It has been observed on the Lomas of Piro in the Osa Peninsula and in Herradura, specifically in the canton of Garabito. It is found in very humid forests between 23-200 m elevation and on the Osa Peninsula it is in primary forest, on clay soils above the mountain rows (Aguilar Fernández et al., 2018).	*Hymenaea courbaril* is known for its antibacterial, antifungal, antiparasitic, and nutritional properties (Alzate Tamayo et al., 2008). In Costa Rica, indigenous people use the vapors from the resin that comes out of the bark to treat asthma; the leaves and bark's infusions are used as a hypoglycemic against diabetes. In the Atlantic region: The decoction of the fruit's rind is used to treat high blood pressure and rheumatism. In the Guanacaste region: the decoction of the leaves and the bark of the trunk and the root are used to relieve stomach pain and as an antidiarrheal (Núñez Melendez, 1975).
Tachia	***Tachia blancoi Al.*** Rodr. & J. Sánchez-Gonz., sp. nov.	Plantae, Leguminosae, Tachia. (*Tachia blancoi)* (Sánchez-González & Rodríguez, 2017)	Endemic to Isla del Coco National Park, it is located at 425 meters above sea level. It has only been observed in the south of the island, near Iglesias Bay and Jesús Jiménez and Las Madres hills (Sánchez-González & Rodríguez, 2017).	Peru's indigenous use the infusion of the *Tachia occidentalis* plant as a bath to treat general ailments. Mayongong Indigenous in Brazil use the plant to treat blood conditions (Struwe & Kinkade, 2013)
Miconia	***Miconia cocoensis*** Almeda & Kriebel., sp. nov.	Plantae, Tracheophyta, Magnoliopsida, Myrtales, Melastomataceae, Miconia Ruiz & Pav. (*Miconia cocoensis*) (Kriebel & Almeda, 2012).	Endemic to Isla del Coco National Park, Costa Rica, found on Iglesias hills and in the foothills near Iglesias Bay and Tesoro Escondido hills (Kriebel & Almeda, 2012).	There are studies on the phytochemical composition of this family that recommend further investigation of this genus (Oliveira Sabbag Cunha et al., 2019). In addition, the *Miconia prasina* plant has been used to treat infected wounds caused by fish bones in Guayanas (González, 2013). And *Miconia fallax* and *M. albicans* have been studied for the treatment against *Bothrops atrox* snake venom (Mourão De Moura et al., 2013).
	Miconia diegogomezii Almeda & Kriebel., sp. nov.	Plantae, Tracheophyta, Magnoliopsida, Myrtales, Melastomataceae, Miconia Ruiz & Pav. (*Miconia diegogomezii)* (Kriebel & Almeda, 2012).	Endemic to the Isla del Coco National Park, Costa Rica, 50-500 m high (Kriebel & Almeda, 2012).	
	Miconia kappellei Kriebel & Almeda., sp. nov.	Plantae, Tracheophyta, Magnoliopsida, Myrtales, Melastomataceae, Miconia Ruiz & Pav. (*Miconia kappellei)* (Kriebel & Almeda, 2012).	It is known only in the Cordillera de Talamanca in Costa Rica, at an altitude of 2000-2100 m (Kriebel & Almeda, 2012). Utility: No medicinal uses have been reported for this species.	
	Miconia ricardoi Almeda & Kriebel., sp. nov.	Plantae, Tracheophyta, Magnoliopsida, Myrtales, Melastomataceae, Miconia Ruiz & Pav. (*Miconia ricardoi*) (Kriebel & Almeda, 2012).	Costa Rica. Cartago. Guarco canton Tapantí-Macizo de la Muerte National Park, between Salsipuedes and Loma del Indio (Kriebel & Almeda, 2012).	
Alismatales	***Spathiphyllum abelianum*** A. Rojas & J. M. Chaves, sp.nov.	Plantae, Tracheophyta, Liliopsida, Alismatales, Spathiphyllum Schott. (*Spathiphyllum abelianum*) (Rojas-Alvarado & Chaves-Fallas, 2011).	Only one of 0.5 hectares, 1 hectare and 1.5 hectares in the western plateau at an elevation of 350-400m is known on Cocos Island by three populations (Rojas-Alvarado & Chaves-Fallas, 2011).	NASA conducted a study in 1989 that studied different houseplants and their potential to purify the air of pollutants, Spathiphyllum, known as "cunas de Moisés" had good results (Wolverton et al., 1989).
Polypodiaceae	***Lellingeria vargasiana*** A. Rojas & J. M. Chaves, sp.nov.	Plantae, Tracheophyta, Polypodiopsida, Polypodiales, Polypodiaceae, Lellingeria A.R. Sm & R.C. Moran. (*Lellingeria vargasiana*) (Rojas-Alvarado, 2011)	Known only in Costa Rica at an elevation of 400-500m on Isla del Coco (Rojas-Alvarado, 2011)	*Polypodium vulgare* L. has ethnoveterinary uses for the treatment of varicose diseases, jaundice, and parasitic infections. In the EMA, it has been approved for herbal medicinal use as an expectorant for coughs, colds, and occasional constipation (Farràs et al., 2021). Ferns have been medicinally used since ancient Greece, initially the ancient botanists and pharmacists used their roots for topical application. Central and South American Indigenous communities have also used them to treat skin tumors and inflammation. In addition, empirical studies have shown effectiveness against skin conditions such as vitiligo, psoriasis, and atopic dermatitis. The molecular composition of these plants has not been fully defined, but some compounds responsible for these actions and antioxidants have been found, such as caffeic acid, chlorogenic acid, coumaric acid, vanillic acid and ferulic acid, as well as non-phenolic compounds such as adenosine (Parrado et al., 2014).
	Stenogrammitis grammitoides A. Rojas, sp. nov	Plantae, Pteridophyta, Pteridopsida, Polypidiales, Polypodiaceae, Stenogrammitis (Rojas-Alvarado, 2013)	Known only at the place of collection, endemic to Isla del Coco, Costa Rica (Rojas-Alvarado, 2013)	

Rubiaceae	***Bouvardia costaricensis*** C. M. Taylor, sp. nov.	Plantae, Magnoliophyta, Magniolopsida, Gentianales, Rubiaceae, Bouvardia. (*Bouvardia costaricensis*) (Taylor & Gereau, 2010).	It is found in humid forests at 1000-1900 m altitude in the central part of Costa Rica (Taylor & Gereau, 2010).	The predominant secondary metabolites in this family, which have been found over the years, since it is from the oldest families, are iridoids, anthraquinones, triterpenes, indole alkaloids, and other classes. They also contain flavonoids and phenolic derivatives. Bioactive alkaloids are emphasized as they have pharmacological effects. This family has great potential in terms of structural and pharmacological diversity, some of these plants have demonstrated anti-inflammatory, antibacterial, analgesic, mutagenic, antiviral, antioxidant effects and have effects on the vascular and central nervous system (Martins & Nunez, 2015)
	Pentagonia osaensis C. M. Taylor, sp. nov.	Plantae, Magnoliophyta, Magniolopsida, Rubiales, Rubiaceae, Pentagonia. (*Bouvardia costaricensis*) (Taylor & Gereau, 2010)	It is found in humid forests at 1-750 m high in Golfo Dulce, Osa Peninsula and Puriscal (Taylor & Gereau, 2010).	
	Pentagonia gambagam Hammel & Aguilar, sp. nov.	Plantae, Spermatophyta, Magnoliopsida, Rubiales, Rubiaceae, Pentagonia (Hammel, 2015).	Only known in the La Gamba biological corridor, Gambagam sanctuary, Golfito, Costa Rica (Hammel, 2015).	
	Pentagonia osapinnata Aguilar, N. Zamora, & Hammel, sp. nov.	Plantae, Spermatophyta, Magnoliopsida, Rubiales, Rubiaceae, Pentagonia (Hammel, 2015).	Distribution: Endemic plant of the Osa Peninsula, Costa Rica (Hammel, 2015).	
Monstera	***Monstera limitaris*** M. Cedeño, sp. nov.	Plantae, Angiospermae, Araceae, Monstera Adans. (*Monstera limitis*) (Cedeño-Fonseca et al., 2018).	It is found only on the border between Costa Rica and Panama on the banks of small rivers (Cedeño-Fonseca et al., 2018). Utility: No medicinal uses have been reported for this species.	*Monstera deliciosa*'s pulp and ripe tips are used to treat pimples, dry skin on the elbows and feet, as well as to soothe sunburned skin. The soft cover is used as a poultice on bruises and sprains, it is also applied to wounds and contusions (Roberts, 2000). *Monstera adansonii Schott*'s sap is used in the Guyanas to treat necrotic ulcers. The decoction of the crushed plant is used to eliminate boils (González, 2013).
Fabaceae	***Phaseolus angucianae*** Debouck & Araya, sp. nov.	Plantae, Angiospermae, Equisetopsida, Fabales, Fabaceae, Phaseolus (Debouck et al., 2018).	Endemic species of Costa Rica, Fila Costeña Sur, Cerro Anguciana and Fila Cruces (Debouck et al., 2020).	*Cassia fistula L.* a Fabaceae family species, is reported as a laxative and blood purifier, the pulp has anti-inflammatory effects on bumps and bruises. The bark is astringent, and the root is used to treat skin diseases, it is astringent and purgative. The crushed fruits in infusion can be used for calculations and constipation (Rodríguez Navas, 2000).
	Phaseolus albicarminus Debouck & Chaves sp. Nov	Plantae, Angiospermae, Equisetopsida, Fabales, Fabaceae, Phaseolus (Debouck et al., 2020).	An endemic species of Costa Rica, found in the Llano Bonito Hills, south of the Central Valley (Debouck et al., 2020).	
Dryopteridaceae	***Elaphoglossum dragonense*** A. Rojas, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Polypodiales, Dryopteridaceae, Elaphoglossum. (A. Rojas, sp. Nov.) (Rojas Alvarado & Baaijen-Harteveld, 2017).	Endemic, known only in the Cerro Caraigres Protective Zone at 2420-2500 m. (I. Chinchilla & A. Rojas 1978, CR, K, MO) (Rojas Alvarado & Baaijen-Harteveld, 2017).	*Elaphoglossum latifolium* is used in Honduras as an antitussive and emmenagogue. In addition, *Tectaria incisa* leaves' infusion is used in Guyanas as an infertility treatment (González, 2013).
	Elaphoglossum flavosquamum A. Rojas & Baaijen, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Polypodiales, Dryopteridaceae, Elaphoglossum (Rojas Alvarado & Baaijen-Harteveld, 2017).	Endemic, known only in the Cerro Caraigres Protective Zone at 2350-2400 m (Rojas Alvarado & Baaijen-Harteveld, 2017).	
	Elaphoglossum pacificum A. Rojas, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Polypodiales, Dryopteridaceae, Elaphoglossum (A. Rojas, sp. Nov.) (Rojas Alvarado & Baaijen-Harteveld, 2017).	Endemic to Costa Rica in the Cordillera de Talamanca, Chirripó National Park at 2600-2900 m (A. Rojas 2877, CR, INB, MO) and Cerro Caraigres Protective Zone at 2300-2350 m (I. Chinchilla & A. Rojas 1946, CR, MO, USJ) (Rojas Alvarado & Baaijen-Harteveld, 2017).	
	Elaphoglossum pallidosquamum A. Rojas & P. Muñoz, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Polypodiales, Dryopteridaceae, Elaphoglossum (A. Rojas & P. Muñoz, sp. Nov.) (Rojas Alvarado & Muñoz Cambronero, 2017).	Only in the Caribbean sector of the Cordillera de Talamanca in Costa Rica and Cordillera de Los Andes in Ecuador at 2850-3200 m (Rojas Alvarado & Muñoz Cambronero, 2017).	
	Tectaria x epilithica A. Rojas, nothosp. nov.	Plantae, Dryopteridaceae, Tectaria (A. Rojas, nothosp. Nov.) (Rojas Alvarado, 2017a)	Endemic to Isla del Coco at 75-150 m elevation (Rojas Alvarado, 2017a).	

Lomariopsidaceae	***Elaphoglossum x intermedium*** A. Rojas, nothosp. nov.	Plantae, Lomariopsidaceae, Elaphoglossum (A. Rojas, nothosp. Nov.) (Rojas Alvarado, 2017a).	Endemic to Isla del Coco at 350-400 m elevation (Rojas Alvarado, 2017a).	In the Amazon region, their main use is medicinal. There are records of their uses not only to cure diarrhea and the flu, heal wounds, unswell hematomas, soothe pain in the body, stomach, teeth and kidneys but also to cure animals (Gonçalves dos Santos et al., 2024).
Hymenophyllaceae	***Hymenophyllum densipilosum*** A. Rojas, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Hymenophyllales, Hymenophyllaceae, Hymeniphyllum (A. Rojas, sp. Nov.) (Rojas Alvarado, 2017c).	Only known from the Cordillera de Talamanca in Costa Rica at 2435-3000 m (Rojas Alvarado, 2017c).	In the Guyanas they use the whole plant of the Hymenophyllum polyanthos spice, in the form of smokes, inhalations, or rubbing the ashes on their cheeks, as a remedy against vertigo and fainting spells; its infusion is used to wash hands and feet, when pain or cramps (González, 2013).
	Hymenophyllum multicristatum A. Rojas, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Hymenophyllales, Hymenophyllaceae, Hymeniphyllum (A. Rojas, sp. Nov.) (Rojas Alvarado, 2017c)	Known only from the Pacific slope of the Cordillera de Talamanca in Costa Rica at 1680–1766 m (Rojas Alvarado, 2017c).	
Pteridaceae	***Pteris arbelaeziana*** A. Rojas, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Polypodiales, Pteridaceae, Pteris (A. Rojas, sp. Nov.) (Rojas Alvarado, 2017b)	Known only on the Pacific slope of the Cordillera de Talamanca at 2400-2800 m. Costa Rica and probably Panama (Rojas Alvarado, 2017b).	The presence of certain metabolites in Argyrochosma nivea, a species of the Pteridaceae family, could confer pharmacological activities. Various ethnobotanical studies report its uses as antibacterial, hypoglycemic and for spiritual cleansing in aqueous preparations of the leaves of the plant (Minchán-Herrera et al., 2020).
	Pteris caridadae A. Rojas, sp. nov.	Plantae, Equisetopsida, Polypodiidae, Polypodiales, Pteridaceae, Pteris (A. Rojas, sp. Nov.) (Testo et al., 2015).	In the Cordillera de Tilarán, north slope of the Cordillera Central and the Caribbean slope of the Cordillera de Talamanca at 800–1600 m (Rojas Alvarado, 2017b).	

Table II.
Summary of Findings from the Bibliographic Review Across Various Databases

Plant Family	Number of Species	Plant Species	Geographic Distribution	Uses
Gentianaceae	1	Voyria crucitasensis	Very humid tropical forest of the Caribbean slope, Crucitas de Cutris, Alajuela	No medicinal uses have been reported for this species.
Myrtaceae	3	Calyptranthes guanacastensis, Myrcia paulii-jonesii,Myrcia riverae.	Northwest region of Cordillera de Guanacaste, surroundings of Bahía Chal, Osa Peninsula	No medicinal uses have been reported for this species.
Chrysobalanaceae	1	Hirtella crusa	Restricted to the Osa Peninsula in the community of Agua Buena de Rincón	No medicinal uses have been reported for this species.
Passifloraceae	2	Passiflora soliana, Passiflora chimuensis,	Puntarenas and very humid forests of the Caribbean	No medicinal uses have been reported for this species.
Orchidaceae	13	Dracontia montis-mortense, Dracontia pileata, Dracontia viridi-flava, Dracontia hydra, Stelis dies-natalis, Stelis aenigma, Epidendrum jorge-warneri, Platystele sylvestrei, Platystele tica, Sobralia danjanzenii, Sobralia zebrina, Trichosalpinx sanctuarii, Vanilla karen-christianae	Surroundings of San Isidro del General and on the Pacific side of the Cordillera de Talamanca	No medicinal uses have been reported for most of the species identified; however, Vanilla karen-christianae has been associated with a potential commercial use as a fragrance.
Quararibea	1	Quararibea nigrescens,	Found on the Caribbean slope of the Cordillera de Guanacaste	No medicinal uses have been reported for this species.
Hymenaea	1	Hymenaea osanigraseminae	In the Central Pacific, in the Manuel Antonio National Park and in the South Pacific in Golfito and in the Osa Peninsula	No medicinal uses have been reported, but in certain areas, its wood is used, the fruit pulp is utilized in confectionery, and the seeds are employed in handicrafts.
Tachia	1	Tachia blancoi	Endemic to Isla del Coco National Park	No medicinal uses have been reported for this species.
Miconia	4	Miconia cocoensis, Miconia diegogomezii, Miconia kappellei, Miconia ricardoi	Some are endemic to Cocos Island National Park, while others are native to the Talamanca Mountain Range.	No medicinal uses have been reported for this species.
Alismatales	1	Spathiphyllum abelianum	Cocos Island	No medicinal uses have been reported for this species.
Polypodiaceae	2	Lellingeria vargasiana, Stenogrammitis grammitoides	Cocos Island	No medicinal uses have been reported for this species.
Rubiaceae	4	Bouvardia costaricensis, Pentagonia osaensis, Pentagonia gambagam, Pentagonia osapinnata.	Some are high in humid forests at 1000-1900 m altitude in the central part. Other in Golfo Dulce, Osa Peninsula and Puriscal	No medicinal uses have been reported for this species.
Monstera	1	Monstera limitaris	Found only on the border between Costa Rica and Panama	No medicinal uses have been reported for this species.
Fabaceae	2	Phaseolus angucianae, Phaseolus albicarminus	Endemic species of Costa Rica, Fila Costeña Sur, south of the Central Valley	No medicinal uses have been reported for this species.
Dryopteridaceae	5	Elaphoglossum dragonense, Elaphoglossum flavosquamum, Elaphoglossum pacificum, Elaphoglossum pallidosquamum, Tectaria x epilithica A	Endemic, known only in the Cerro Caraigres Protective Zone at 2420-2500 m.	No medicinal uses have been reported for this species.
Lomaripsidaceae	1	Elaphoglossum x intermedium	Endemic to Isla del Coco at 350-400 m elevation	This family does not report any ethnobotanical use.
Hymenophyllaceae	2	Hymenophyllum densipilosum, Hymenophyllum multicristatum	Only known from the Cordillera de Talamanca in Costa Rica at 2435-3000 m	No medicinal uses have been reported for this species.
Pteridaceae	2	Pteris arbelaeziana, Pteris caridadae	Only on the Pacific slope of the Cordillera de Talamanca at 2400-2800 m	No medicinal uses have been reported for this species

This table considers a comprehensive review of original articles, both in English and Spanish, focusing on species from Costa Rica that are endemic, recently discovered (2010–2020), have limited studies, exhibit ethnobotanical uses, or belong to families with reported medicinal uses.

Conclusions

The present review identified 46 plant species discovered in Costa Rica between the years 2010-2020, distributed in 18 botanical families that can be found in different parts of the country, the vast majority belonging to families with documented traditional medicinal uses, however the findings revealed a significant unexplored pharmacological potential of the species of almost 85%.

Therefore, it is necessary to study more extensively the large number of plant species that have been discovered in Costa Rica, the main limitations include at this time the scarcity of detailed phytochemical studies and the lack of systematic documentation of the traditional uses of these species, so specific research is required on the molecular and phytochemical profiles of these species, prioritizing those belonging to families with documented medicinal uses such as species of the Myrtaceae family that has been reported in the treatment of influenza, cough, diarrhea, antiemetic, among others; or as the Passifloraceae family that has been described its use in respiratory tract congestion, insomnia, skin conditions, also in the treatment of intestinal parasitosis.

Likewise, it is important for the preservation of Costa Rican culture to carry out updated research on the ethnic uses of endemic plants in Costa Rica, thus preserving their traditional use and the potential of natural medicine in the country.

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Character harmonisation in adolescence: psychological profiles, coping strategies and implications for well-being

Гармонізація характеру в підлітковому віці: психологічні профілі, стратегії подолання та наслідки для благополуччя

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Abstract

The article highlights the topical issue of character harmonisation in adolescence, which is an important aspect of holistic personality development and social adaptation. Character harmonisation is seen as a complex integration process that combines personal traits, emotional reactions and behavioural patterns. At the same time, character harmonisation remains relatively poorly researched, which emphasises the relevance of studying its psychological mechanisms. The purpose of the study was to determine the individual psychological characteristics of young men with different levels of character harmonisation. The tasks included

Анотація

У статті висвітлюється актуальна проблема гармонізації характеру в юнацькому віці, яка є важливим аспектом цілісного розвитку особистості та соціальної адаптації. Гармонізація характеру розглядається, як складний інтеграційний процес, що об'єднує особистісні риси, емоційні реакції та моделі поведінки. Водночас гармонізація характеру залишається відносно мало дослідженою, що підкреслює актуальність вивчення її психологічних механізмів. Мета дослідження полягала у визначенні індивідуально-психологічних особливостей юнаків, із різним рівнем гармонізації характеру. Завдання включали оцінку рівня гармонізації характеру за допомогою методики

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assessing the level of character harmonisation using the HCA (Harmony Character Assessment) methodology, analysing the relationship between character harmonisation and basic personality traits, and studying differences in coping strategies between young men with high and low levels of character harmonisation. The empirical study was conducted among students (N = 60) aged 18-25 years. The following methods were used: theoretical and methodological analysis, psychodiagnostic techniques, and mathematical and statistical approaches. The psychodiagnostic complex included the HCA technique and the PTQ (Personality Traits Questionnaire). All stages of the study complied with ethical standards, including the principles of voluntariness, confidentiality and legal protection of research subjects, taking into account the norms of bioethics. The findings allowed us to reveal the psychological mechanisms of character harmonisation, identify the relationship between the level of harmonisation and key personality characteristics, and determine the role of coping strategies in this process. The study is important for improving the system of psychological support for young people aimed at developing a harmonious personality, its adaptation to social conditions and improving psychological well-being.

Keywords: socialisation, habitus, subject, person, personality.

HCA (Harmony Character Assessment), аналіз взаємозв'язків між гармонізацією характеру й основними особистісними рисами, а також дослідження відмінностей у копінг-стратегіях між юнаками з високим і низьким рівнями гармонізації характеру. Емпіричне дослідження проведено серед студентів (N = 60) віком 18–25 років. Також було використано: теоретико-методологічний аналіз, психодіагностичні техніки та математико-статистичні підходи. До психодіагностичного комплексу входили методика HCA та опитувальник PTQ (Personality Traits Questionnaire). Усі етапи дослідження відповідали етичним стандартам, зокрема принципам добровільності, конфіденційності та правового захисту суб'єктів дослідження з урахуванням норм біоетики. Отримані результати дозволили розкрити психологічні механізми гармонізації характеру, виявити взаємозв'язки між рівнем гармонізації та ключовими характеристиками особистості, і визначити роль копінг-стратегій у цьому процесі. Дослідження має важливе значення для вдосконалення системи психологічної підтримки молоді, спрямованої на розвиток гармонійної особистості, її адаптації до соціальних умов та підвищення психологічного благополуччя.

Ключові слова: соціалізація, габітус, суб'єкт, людина, особистість.

Introduction

Modern psychological science is increasingly focusing on the problem of character harmonisation in adolescence, due to its importance for the holistic development of the individual. Character harmonisation is seen as a complex process of combining personal traits, emotional reactions and behavioural patterns into a balanced and integrated structure. This concept is of particular importance during adolescence, which is characterised by significant physiological, emotional and social changes. Given the importance of character harmonisation for overall psychological well-being and successful social adaptation, the study of this phenomenon is extremely relevant. However, despite its significance, character harmonisation remains a relatively under-researched phenomenon in modern psychology.

The purpose of the study is to investigate the individual psychological characteristics of young men with different levels of character harmonisation.

In accordance with the formulated purpose of the study, a number of research **objectives were identified,** namely:

- Determine the level of character harmonisation in young men using the HCA (Harmony Character Assessment) methodology.
- To investigate the relationship between the level of character harmonisation and the main personality traits of young men using the PTQ (Personality Traits Questionnaire).
- To analyse the individual psychological characteristics of young men with different levels of character harmonisation.
- To identify key differences in personal characteristics between groups of young men with high and low levels of character harmonisation.

The object of the study is the harmonisation of personality in adolescence.

Research methods: theoretical and methodological analysis, psychodiagnostic methods and mathematical and statistical methods.

The psychodiagnostic complex includes: 'Harmony Character Assessment (HCA) (Pavlyk, 2013), Personality Traits Questionnaire (PTQ) (Galyan, 2011) or (Arshadi et al., 2018).

The sample consisted of students of the Faculty of Psychology and Pedagogy of the National Pedagogical University named after K.D. Ushynsky (N = 60), whose age range is from 18 to 25 years. The procedure for organising and conducting an empirical study complied with the key ethical principles regulated by the principles of deontology and bioethics. All participants provided informed consent to participate at the time of the study, which ensured compliance with ethical standards, including confidentiality, voluntariness and legal protection of participants.

The following sections of this article will present a detailed review of the literature, the methodology used to conduct the study, the results obtained, and finally, the conclusions derived from the study. The study is limited to a specific sample of students and relies on self-report measures.

Literature review or theoretical framework

The theoretical analysis of scientific sources allows us to trace the evolution of views on character from ancient times to modern psychology. In classical philosophy, character was viewed as a set of stable psychological traits that determine the individual originality of a person and his or her behavioural reactions to external stimuli. In the works of greek philosophers, character was seen as the basis of moral and ethical principles that contribute to the proper functioning of an individual in society. Platon, in his theory of the soul, defined character as an integral part of mental harmony, which guarantees a balanced and moral life of an individual that meets the requirements of society. (Mykhalska & Shchavurskyi, 2006). Aristotle, in turn, emphasised that a harmonious character is the result of the interaction of reason and moral virtues that ensure an appropriate attitude towards oneself and others. Thus, in classical philosophy, harmony is understood as the internal coherence of various aspects of a personality that allows a person to act in accordance with social norms and moral imperatives (Bulakh & Skrypchenko, 2008; Grigoriou, 2015).

Further, in the psychophysiological context, character was considered through the prism of temperament, which was an important component of ancient theories. Hippocrates defined temperament as the basis for the formation of individual characteristics of a person, which are closely intertwined with his or her character. He emphasised that temperament types (sanguine, choleric, phlegmatic, melancholic) are basic for the development of certain characteristic traits in a person. According to these views, temperament is important for the further socialisation of an individual and his or her ability to adapt to the conditions of the social environment. In adolescence, when character is being actively formed, the influence of temperament is significant, as it affects emotional reactions and behavioural strategies of a young person. At the same time, temperament determines the limits within which harmonious or disharmonious character traits can occur, which makes the study of this phenomenon in adolescence particularly important (Mahler et al., 2012).

In modern psychology, character harmonisation is seen as a process that includes the integration of various mental and personal components of a personality into a single, stable system. Harmonisation means not only the absence of conflicts between individual traits, but also the adaptation of these traits to social and cultural norms, which allows an individual to achieve a high level of social adaptation and personal development. In the context of adolescence, this process is of particular importance, as it is during this period that self-awareness is formed, and the need for self-expression and interaction with other people increases. Harmony of character during this period helps to ensure not only psychological well-being, but also successful socialisation, which is an important factor for further personal development. In turn, disharmony of character, which can manifest itself in the form of inconsistency of internal motives, emotions and behavioural reactions, can become the basis for the development of various mental and social problems that require special psychological intervention (Babchuk et al., 2023).

Character harmonisation, as a process of creating a stable psychological state, is an important aspect of personality development, especially in adolescence. According to scientific interpretations, this process is

associated with the elimination of negative psychological qualities that may interfere with proper social and interpersonal interactions. Based on the philosophy of Socrates, character harmonisation involves the pursuit of moral perfection, which is the basis for harmonious interaction with the world around us. An important element of this process is the formation of inner maturity based on moral and ethical principles such as honesty, justice, tolerance and education. Especially in adolescence, when an individual is just beginning his or her journey in society, achieving character harmony becomes a determining factor for the development of healthy social and psychological relationships, as it is during this period that the ability to self-awareness and acceptance of ethical norms that regulate behaviour in society is formed.

Modern empirical research is increasingly paying attention to the game as one of the ways to improve the perception and adaptation of the adolescent's character. In today's scientific cognition, the starting point, rational programme and scenario for the search and implementation of psychological means of productive life of the modern society is increasingly the game - a socio-cultural phenomenon and an integral factor of self-realisation of a person as a subject, personality and individuality in the process, space and time of its philo- and ontogenesis.

The researcher Polishchuk V.M. emphasises the usefulness of didactic game as a means of conflict-free socialisation of adolescents in the process of their daily communication. By creating the right conditions for the realisation of their needs for self-affirmation, self-expression and self-education, the teacher takes into account and properly directs the desire of everyone to reveal their personal traits, qualities, earn respect in the team and take a certain place in it. The didactic game eliminates possible problems associated, on the one hand, with the adolescent's awareness of his/her adulthood, the need to be an authoritative adult, and, on the other hand, with possible competitive reactions in situations of grouping with peers; moreover, this type of game is one of the auxiliary ways to harmonisation the adolescent's character. The adolescent brings not only imagination to the game, but also sets himself complex creative tasks, to solve which he needs deep and solid knowledge that allows him to come to certain independent conclusions. That is why the game reflects the existence of a modern socialised individual and is an objective reflection of a new era that has no relevant historical comparisons. (Polishchuk, 2019)

According to Epicurus, the harmonisation of character through the development of moral virtues and ethical standards is the basis for social adaptation and inner well-being. In adolescence, when a person goes through significant changes in the social and psychological spheres, it is especially important to master the moral and ethical principles that form the basis of interaction with other people. Noting the importance of moral values, Epicurus stressed that harmony is the result of a conscious choice between natural and social needs. This is reflected in the process of character harmonisation, which allows young people to adapt to new social roles, understand their own emotional and cognitive processes and, as a result, achieve psychological balance, which contributes to their self-realisation and successful interaction in society (Rodgers, 1963).

However, despite the great influence of moral and ethical practices, the traditions of the East, although they ensure the achievement of a certain external harmony - calmness, high spirits and psychological balance - they do not always solve the problem of deep harmonisation of character. In particular, Eastern practices promote the development of higher psychological functions such as imagination, feelings and will, but often do not pay due attention to the development of moral and spiritual traits such as altruism, the ability to forgive or admit one's own guilt. This, in turn, can lead to young people focusing on external aspects of harmony and not always being able to effectively cope with real life difficulties that require inner maturity and moral fortitude. Therefore, in order to achieve true character harmony, which includes deep moral awareness and the ability to constructive interpersonal interactions, it is important to integrate self-development practices with ethical and psychological approaches aimed at improving not only the external but also the internal component of the personality (Maddi, 2006).

Spiritual and moral factors of character harmonisation were an important subject of research in medieval Christian anthropology, in the context of which the harmony of the individual was seen as the unity of spirit, mind, feelings and will. Philosophers and theologians of this period emphasised the importance of developing inner moral integrity as the basis for harmonious character formation. Christian anthropology attempted to synthesise religious and philosophical knowledge, laying the foundation for understanding harmony as an integrative process that combines the spiritual and psychological aspects of the individual. They emphasised the importance of moral virtues, such as modesty, patience and charity, which form the basis for creating a harmonious character. This approach assumes that true harmony is the result of an individual's inner transformation through religious and moral improvement (Pavlyk, 2015).

Ryan R. M. & Deci E. L. (2004) in their works also highlighted the importance of the unity of mind and body as the basis of the integrity of character, which determines the moral state of a person. According to his views, character is a complex system formed on the basis of moral virtues that resist negative traits such as selfishness, anger, envy and other vices. The violation of this unity, which often occurs due to the development of egoism, is seen as a source of disharmony in the personality.

Egoism, being the psychological basis for the development of a disharmonious character, causes a violation of the hierarchy between the spiritual, mental and bodily needs of a person. In this context, a person may lose the ability to harmoniously define himself or herself, as selfish aspirations displace the need for moral self-improvement, which leads to the development of persistent destructive skills (Willemsen & Waterman 1991; Ryan & Deci, 2000).

On the basis of egoism, natural human needs are transformed into passions - persistent destructive psychological tendencies that, over time, take the form of destructive character traits. Natural instincts that are not regulated by moral principles can become a source of suffering and internal conflicts, which become the basis for the development of a disharmonious character. In adolescence, when a personality is still in the process of formation, it is important to recognise and overcome such manifestations, because this is the age when a young person is actively looking for his or her place in society and shaping his or her character.

Therefore, spiritual and moral practices aimed at self-development and improvement of moral virtues are important for achieving harmony in the mental and personal development of a young person, as well as for overcoming the destructive tendency that can arise as a result of the unbalanced development of natural instincts and social roles (Asieieva et al., 2022).

The basis of harmonious character formation is the development of morality, which acts as an intrapersonal quality that regulates the behaviour of an individual. Morality determines a person's ability to distinguish between good and evil, as well as his or her desire for moral improvement. An essential aspect of morality is moral feeling, which is a psychological unit consisting of the ability to evaluate actions in terms of right and wrong. This feeling is an important component of the development of a harmonious character, as it serves as a guide for internal self-determination and evaluation of actions. With the help of moral sense, which is manifested in the awareness of their actions and their compliance or non-compliance with moral norms, young people are able to adapt to social requirements and act as active subjects of moral choice, showing a commitment to goodness and true values (Weinhold & Bradshaw, 2008).

Moral sense develops through the interaction of internal and external factors. In adolescence, when social and personal guidelines are being actively formed, the moral law - an inner sense of rightness and justice - plays an important role. It is the moral law that determines the boundaries of behaviour, influencing the actions of the individual and ensuring the regulation of his or her moral needs. This inner sense of responsibility for one's own actions is the basis for achieving harmony in character, as it helps a person to build his or her own behaviour not only in accordance with social norms, but also on the basis of deep personal convictions. As a result, a harmonious character forms the ability of an individual to be guided by higher ethical principles that go beyond external influences and social requirements.

Conscience, which is an integral part of the moral law, performs the functions of self-awareness and self-control, determining the level of moral maturity of a person. In adolescence, conscience develops through constant interaction with moral norms and social requirements. It contributes to the formation of an independent choice, which is not limited to external moral norms, but includes an internal judgement of the rightness or wrongness of one's actions. Conscience is manifested through the feeling of guilt for an immoral act and is an important factor in the process of moral self-regulation. It ensures the integrity of the personality, helping to make decisions that do not contradict internal moral convictions, and thus contributes to the harmonisation of character, which is a necessary stage in the formation of a mature and emotionally balanced personality (Kuhl, 1996).

The purposeful study of character disharmonies in the context of psychotherapeutic theories began in the late eighteenth century, when philosophers and psychotherapists began to focus on the influence of personal traits on the mental state of a person. Social and behavioural aspects, such as antisociality, aggressiveness, lack of guilt, and the phenomena of "moral insanity", became the main parameters that determine disharmonious character. These factors have been recognised as key to the development of pathological conditions that interfere with an individual's normal social adaptation. Psychotherapists, including

J. Pritchard, D. Henderson and B. Karpman, focused on the study of such psychological characteristics as emotional instability and pathological tendencies that determine the ability of an individual to integrate into society. The study of these aspects is extremely important for the process of character harmonisation, as it allows to identify the main sources of disharmony and develop psychotherapeutic approaches to correct them (Rainwater, 1979).

Later, the study of characterological disharmonies was developed in a number of psychotherapeutic and psychological movements, in particular in Germany, where psychiatrists and psychologists analysed the relationship between characterological features and mental disorders. They argued that certain personality types are prone to developing psychopathologies, which in turn affects the social adaptation of the individual. In turn, psychiatric theories complemented theories of character development, pointing to the importance of genetic and biological factors in the formation of disharmonious character traits. Such studies have made it possible to identify patterns of functioning of characterological systems both in normal and pathological conditions, which has become the basis for more effective methods of psychotherapeutic intervention (Rotter, 1982).

In the course of further research, the problem of character harmony was considered from different theoretical perspectives, in particular, through the psychoanalytic approach, social psychological theory and humanistic direction. In these approaches, character harmony was defined through the level of development of mental functions, such as intellectual maturity, emotional stability and self-awareness, as well as through the ability to social and psychological adaptation. The development of these functions is an important component of the process of character harmonisation in adolescence, as it is during this period that social guidelines and internal beliefs are actively formed, which influence the further formation of the personality. The psychological aspects of character harmonisation in this context become key to understanding how young people go through the processes of adaptation, self-determination and moral growth (Kuhl & Keller, 2008).

According to I. D. Bech, the moral formation of an individual is an important condition for his or her psychological development, as it allows the subject to form the ability to make moral decisions, moral choices and actions. In this context, morality is considered to be an integral part of the ontogenesis process, which allows an individual to integrate into society, maintain mutual understanding and harmonious relationships with other people. Moral consciousness forms the basis for determining what is good or bad, right or wrong, and thus contributes to the development of internal guidelines for behaviour that meets social standards and requirements. An important component of this process is moral sense, the ability to be aware not only of the interests of oneself but also of others, which allows a person to develop as a socially responsible subject (Beh, 2018).

The process of moral development in adolescence is accompanied by the formation of moral consciousness, which ensures the stability of psychological development. Moral self-awareness is the result of the integration of personal beliefs, internal values and social requirements that allow a person to determine their moral guidelines. At this age, the ability to reflect is important, i.e. the ability to evaluate one's actions and choices independently. This reflection allows young people not only to enrich their moral understanding but also to adapt effectively to changes in the social context. Social institutions, such as family, school and peers, play an important role in the development of moral consciousness, through interaction with which the idea of moral norms and responsibility for one's own actions is formed. Harmonisation of character in adolescence involves an active process of internal self-determination, moral growth and personal improvement, which is carried out through the development of moral consciousness and the ability to make conscious moral choices (Kroger, 2007).

In this context, harmonious character development is the result of the integration of spiritual orientation, the need to find the meaning of life and self-actualisation of the individual. The formation of a balanced habitus allows a person to integrate personal traits, behavioural patterns and emotional reactions, contributing to their harmonisation. A key aspect is the development of internal motivation for spiritual growth, which allows an individual to achieve high levels of self-knowledge and awareness. Adolescence is a period of intensive formation of moral guidelines, when a person actively seeks answers to questions about his or her place in the world and the meaning of his or her own actions. The search for the meaning of life allows for a deeper understanding of one's own spiritual essence and, in turn, ensures the process of character harmonisation, reducing the likelihood of developing destructive or neurotic traits (McHale et al., 2009).

The formation of coping strategies contributes to successful adaptation to difficult life circumstances and plays a key role in ensuring emotional balance. The emergence of neurotic manifestations in a person's character is directly related to the lack of inner harmony that arises from an insufficient level of morality, weak self-control and lack of awareness of one's own attitudes. According to Adrian van Kaam, such destructive behaviours as rigidity and obsessions can only occur against the background of immorality, which is manifested in the insufficient development of moral principles and internal beliefs. A person with such traits is often unable to perceive higher values, which leads to the fact that their behaviour is determined by external influences rather than internal moral guidelines. This uncertainty and lack of internal stability cause numerous psychological disorders and difficulties in social adaptation (Wann, 1974; Rotter, 1975).

Habitus, as an integrated system of social and cultural guidelines, plays an important role in the formation of moral attitudes and self-control in adolescence, contributing to the harmonisation of character. The development of coping strategies in this period helps an individual to effectively cope with stressful situations arising in the process of socialisation and self-determination. The formation of a healthy habitus provides the basis for internal stability and moral choice, which is an important aspect of personal development. Through the development of coping strategies, young men gain the ability to adapt to social change and constructively resolve conflict situations, which is key to their social responsibility and integration. The combination of conscious coping strategies with a harmonious habitus allows young people to achieve inner harmony, avoid destructive behaviours and build mature interpersonal relationships.

The development of moral attitudes and self-control is of particular importance for the harmonisation of character in adolescence. It is at this stage of life that the foundations of not only personal identity but also social responsibility are formed. Moral principles, as internal beliefs that regulate behaviour, are necessary to avoid the formation of destructive character traits that may hinder successful adaptation to society. Adolescence is also a time of developing the ability to self-reflection, when a person gains experience of making conscious moral choices, which is an important step towards harmonising character. The ability to understand one's emotions, control reactions and be responsible for one's own actions contributes to the formation of a harmonious personality capable of constructive relationships with other people and with oneself (Kroger et al., 2013; Riina & McHale, 2012).

Therefore, in adolescence, the formation of moral attitudes and the development of self-control are of particular importance for the harmonisation of character, which ensures the optimal integration of individual and social aspects of the personality. At this stage of personal identity development, internal beliefs are formed that regulate behaviour and are necessary to prevent the development of destructive character traits that can negatively affect social adaptation. Moral choice and self-reflection in adolescence contribute to the formation of the ability to emotional self-control and responsibility for one's own actions, which, in turn, are important prerequisites for the development of a harmonious personality. The ability to reflect, understand and regulate emotional reactions is critical for the development of constructive interpersonal relationships and internal stability, which contributes to social integration and mental maturity.

Methodology

For the empirical study of the psychological characteristics of the harmonisation of young men's character, two methods were chosen that allow assessing both the level of general harmony of the personality and specific traits that contribute to its development or impede this process. The first methodology, the Harmony Character Assessment (HCA), allows for the assessment of the integration of internal psychological components of a personality, including moral and emotional characteristics, as well as interaction with society. This tool helps to identify the extent to which a person is capable of self-control, adaptation in different social contexts, and maintaining internal balance, which are essential aspects of character harmonisation in adolescence. In addition, the methodology allows us to identify not only the level of adaptability, but also psychological barriers that may hinder the development of character harmony, including problems related to low self-awareness or inconsistent behaviour.

The second methodology used is the Personality Traits Questionnaire (PTQ), which provides a detailed assessment of the range of individual character traits that are important for the harmonious development of a person. This questionnaire is based on the assessment of various aspects of personality, such as emotional stability, extraversion, sense of responsibility, as well as the ability to empathise and adapt to changing

environmental conditions. The use of this tool allows us to identify whether young people have certain traits that can be both a resource for character harmonisation and an obstacle to this process. An important aspect is that this questionnaire allows to distinguish between traits associated with natural psychological resilience and those that may arise under the influence of social or emotional difficulties that often accompany adolescence.

The study sample consisted of 60 students of the Faculty of Psychology and Pedagogy of the K.D. Ushynsky National Pedagogical University. The age range of the participants is from 18 to 25 years, which is typical for adolescence, when both the foundations of character and social attitudes that determine further personality development are intensively formed. This age range allows us to focus on the critical stages of forming a harmonious character, when moral, emotional and social aspects are integrated, which are important for further socialisation and adaptation in society. The sample is representative for the study of psychological aspects of character harmonisation in the youth environment, as students at this age often face numerous emotional, social and moral challenges that directly affect their character development.

Results and discussion

The correlation analysis allows for a deeper understanding of the relationship between the level of character harmonisation and the individual psychological characteristics of young men. The analysis revealed that a high level of character harmony is closely related to such traits as emotional stability, social adaptation, and the ability to self-organise and self-regulate. Young men with a high level of character harmonisation demonstrate high internal stability, the ability to effectively cope with emotional difficulties, and successfully adapt to social conditions, which are important aspects of psychological health and well-being. They are more open to change, demonstrate mature self-esteem and readiness for self-control, which allows them to respond adequately to stressful situations and build constructive interpersonal interactions.

In contrast, a low level of character harmonisation is associated with high levels of anxiety, aggressiveness and deficit self-esteem. Young men with a low level of harmony are characterised by emotional instability, low adaptability to changing social conditions, and a tendency to conflict. This level of harmonisation indicates the presence of psychological barriers that hinder the development of social maturity and effective self-determination. A low level of harmony can be caused by various internal conflicts, lack of adequate self-esteem, and severe emotional experiences that prevent a young person from building healthy interpersonal relationships and finding their place in society.

The correlations between the results of the two methods (HCA and PTQ) allow us to clearly classify young men according to the level of harmonisation of their character and the corresponding personal characteristics. According to the results, it is possible to identify separate groups of students with high, medium or low character harmony. Young men with a high level of character harmonisation are characterised by high rates of social adaptation, emotional stability and self-control, which confirms the presence of healthy mental mechanisms and a balanced internal personality structure. In turn, groups with a low level of harmony are characterised by certain difficulties in social integration, increased anxiety, aggressive reactions and difficulties in self-control, which requires additional attention to psychological assistance and support in the process of personal development.

In order to analyse in more detail the individual psychological characteristics of young people who differ in the level of character harmonisation, the sample was clustered on the basis of the results of the HCA test. Clustering allowed us to identify two main groups: a group of young men with a high level of character harmony (HCA+) and a group with a low level of character harmony (HCA-). The first group consisted of 32 participants, while the second group included 28 people. This classification allowed for a more in-depth analysis of psychosocial characteristics specific to each group, which opens up new opportunities for understanding the psychological aspects of character harmonisation in adolescence.

The results of the study revealed significant differences between the groups in terms of both social and emotional and psychological aspects. Representatives of the HCA+ group demonstrated high levels of social adaptation, which indicates their ability to successfully integrate into different social environments, easily establish contacts and maintain stable interpersonal relationships. High emotional stability scores also indicate the ability of this group to effectively cope with emotional stress, which is an important sign of mental maturity. Moreover, these participants demonstrated a high level of self-organisation, which confirms their ability to self-control and achieve their goals despite external difficulties and challenges.

In turn, the HCA- group showed low indicators of social adaptation, which indicates difficulties in establishing social contacts and adapting to changing social environment. This may be the result of insufficient ability to resolve interpersonal conflicts or reduced self-confidence in social interactions. In addition, this group demonstrates high levels of anxiety and stress reactivity, which may indicate a tendency to experience severe emotional stress in response to external stimuli. Such psychological characteristics can make it difficult to adapt to difficult life situations and contribute to the development of depressive symptoms or emotional instability. In addition, the high level of social maladjustment in this group indicates that they face difficulties in building social relationships, which can be both a consequence and a factor that enhances low levels of character harmony.

According to the results of a correlation analysis based on the methodology for determining the level of character harmony, in the group of young men with a high level of character harmony, positive correlations were found between the level of character harmony and such important personality traits as emotional maturity, communication skills, flexibility in conflict resolution, and the ability to self-actualise. Of particular importance is the high correlation between the level of character harmonisation and self-esteem in the HCA+ group. The results indicate that individuals with a high level of character harmony have an adequate, mature self-esteem that reflects the internal balance of the individual. They are able to objectively assess their strengths and shortcomings, which allows them to make effective changes in behaviour and adapt to various social conditions. Inner balance and self-esteem, in turn, create a stable basis for achieving higher levels of self-realisation and self-actualisation, which is the result of harmonious personality development in adolescence. These aspects are undoubtedly important components of character harmony that contribute to the development of an individual's potential and ensure success in achieving life goals.

In contrast, in the group with a low level of character harmony (HCA-), negative correlations were found with similar indicators, indicating a decrease or absence of these traits in the process of personal development. In particular, young men with low levels of harmony demonstrate lower levels of emotional maturity, which is manifested in their tendency to impulsive reactions, emotional lability, and difficulties in self-regulation. In addition, they have limited communication skills and are unable to adequately resolve social conflicts, which indicates a low efficiency of their social adaptation. Negative correlations with self-esteem indicate deficiencies in self-definition and self-esteem, which may be associated with low self-esteem, loss of self-confidence, or critical beliefs about one's own worth. This is one of the main factors that keep individuals in a state of internal imbalance, which creates additional difficulties in developing a harmonious character.

Table 1.
Correlations between the level of character harmonisation (HCA) and personality traits on the PTQ scale

Traits	The level of character harmonisation (HCA	Correlation value (r)
Emotional stability	HCA+	+0.82
Social adaptation	HCA+	+0.76
Self-organisation	HCA+	+0.78
Anxiety	HCA-	-0.85
Aggression	HCA-	-0.79
Self-assessment	HCA+	+0.71
Deficit self-esteem	HCA-	-0.72
Stressfulness	HCA-	-0.80

The author of Table 1 is Yatsyshyna Anastasiia.

According to the results of the correlation analysis, there are clearly expressed correlations between the level of character harmonisation (HCA) and personality traits, which indicate important aspects of the mental development of young men in the context of character harmonisation. The results show that a high level of character harmony (HCA+) is significantly correlated with a number of positive psychological traits, including emotional stability (r = +0.82), social adaptation (r = +0.76), self-organisation (r = +0.78), and positive self-esteem (r = +0.71). This indicates that young men with a high level of character harmony are able to effectively control their emotions, which allows them to maintain internal balance even in stressful situations. Emotional stability is a critical factor in a young man's ability to adapt to society and interact with others. Since social adaptation and self-organisation are important components of overall psychological maturity, their high correlation with character harmony emphasises their importance for

personality development in adolescence. High self-esteem in the context of harmonious personality development is also an indicator of internal stability and confidence, which allows young men to interact appropriately with other people, perform social roles, and succeed in their life goals.

In the opposite group, where the level of character harmonisation is low (HCA-), negative correlations are observed with such traits as anxiety (r = -0.85), aggressiveness (r = -0.79), deficit self-esteem (r = -0.72) and stressfulness (r = -0.80). This indicates that young men with low levels of character harmony are prone to anxiety and aggressive reactions, which, in turn, significantly impairs their social interactions and ability to adapt to difficult situations. Low levels of emotional stability and high levels of anxiety and stress lead to difficulties in interacting with others, developing social relationships, and maintaining internal balance. Also, a negative correlation with deficit self-esteem indicates problems in self-determination, which can lead to a decrease in self-esteem and internal dissatisfaction. This situation becomes the basis for the development of social maladjustment, which makes it difficult to achieve personal and social success.

Summing up the results, we can conclude that the level of character harmony is important for the development of young men in adolescence. A high level of character harmony contributes to the development of social, emotional and cognitive functions, which ensures a high level of adaptation and self-actualisation. On the other hand, low levels of character harmony are closely associated with difficulties in emotional regulation, interpersonal interactions, and self-understanding, which hinders the development of a full and healthy personality. Thus, these correlations allow for a deeper understanding of the psychological mechanisms that influence character harmonisation in adolescence and identify key aspects that should be focused on in psychological and pedagogical correction and support for the development of young men.

In turn, the construction of personality trait profiles for two groups of young men with different levels of character harmonisation revealed significant differences in their psychological structure and adaptability to the environment. Representatives of the group with a high level of character harmony (HCA+) have a more mature and adaptive personality structure, which is manifested in their ability to effectively resolve conflicts, maintain emotional stability and interact with other people. The profile of this group is characterised by high levels of self-organisation, which indicates the ability to plan and structure their behaviour, as well as high social adaptability, which indicates successful integration into various social groups and environments. An important aspect is also emotional maturity, which allows these young men to remain calm and rational in stressful situations, which is an important condition for harmonious personal development in the face of the social and emotional challenges of adolescence.

In contrast, representatives of the group with a low level of character harmony (HCA-) demonstrate a profile characterised by certain psychological difficulties that complicate their adaptation in society. Explicit features of social maladjustment, such as difficulties in building and maintaining interpersonal relationships, lack of effective strategies for social interaction, indicate an inability to respond adequately to social demands and challenges. At the same time, high levels of anxiety and aggressiveness indicate a disorder of emotional regulation, which makes it difficult to resolve conflict situations and lead to mutual understanding in peer and adult groups. The presence of such traits can be the basis for the development of stressful and emotionally exhausting situations, which, in turn, contributes to even greater social maladjustment and disruption of personal balance.

These differences in the personality profiles of the two groups provide important insights for understanding the mechanisms of character harmonisation in adolescence. Young men with a high level of character harmony have the ability to self-regulate and adapt, which has a positive impact on their emotional stability and social interactions, while those in the low character harmony group have significant difficulties in emotional and social adaptation, which can lead to a deterioration in the quality of life and personal achievements. An in-depth study of these profiles allows us to create targeted psychological support programmes aimed at increasing the level of character harmony, developing emotional maturity and social adaptation, which are important conditions for the successful development of young men in difficult social conditions.

For a more detailed understanding of the psychological and structural differences between groups of young men with high and low levels of character harmony, a table was constructed that reflects the profiles of personality traits of these groups. This approach allows us to clearly demonstrate the main differences in such key psychological and mental characteristics as social adaptation, self-organisation and emotional

stability. The analysis of the table shows that young men with a high level of character harmony (HCA+) have consistently high scores in all these categories, which indicates their ability to effectively adapt to the social environment, organise their own activities and emotional maturity (Pavlyk, 2013). High social adaptation scores in the HCA+ group indicate the ability of these young men to successfully interact with others, while self-organisation scores show their ability to plan and implement their tasks. In addition, a high level of emotional stability helps them to maintain balance in stressful situations.

Table 2.
Personality trait profiles of young men with high and low levels of character harmony

Traits	Group HCA (high level of character harmony)	Group HCA (low level of character harmony)
Emotional stability	High level (+0.82)	Low level (-0.80)
Social adaptation	High level (+0.76)	Low level (-0.79)
Self-organisation	High level (+0.78)	Low level (-0.72)
Anxiety	Low level (-0.85)	High level (+0.85)
Aggression	Low level (-0.79)	High level (+0.79)
Self-assessment	High level (+0.71)	Low level (-0.72)
Deficit self-esteem	Low level (-0.72)	High level (+0.72)
Stressfulness	Low level (-0.80)	High level (+0.80)

The author of Table 2 is Asieieva Yuliia.

The analysis of the table results shows that the group of young men with a high level of character harmony (HCA+) demonstrates significantly better indicators in all key categories, including social adaptation, self-organisation and emotional stability. A high level of social adaptation indicates the ability of young men in this group to interact effectively with others, successfully build relationships with other people and integrate into the social space. Such young men are able to successfully cope with social challenges, which is an important aspect of harmonious personal development. High levels of self-organisation and emotional stability allow them to plan their activities, implement their tasks and remain calm in stressful situations, which has a positive impact on their mental health and effectiveness in life processes. In addition, self-esteem scores (+0.71) emphasise the importance of internal balance and adequate self-esteem for achieving character harmony.

On the other hand, the group of young men with low levels of character harmony (HCA-) shows significantly lower scores in the same categories. A low level of social adaptation indicates difficulties in establishing and maintaining interpersonal relationships, which can lead to social isolation and problems in interacting with other people. Decreased self-organisation indicates difficulties in planning and implementing tasks that require strategy, as well as a low ability to self-control. A decrease in emotional stability, in turn, indicates a high sensitivity to stressful situations, which leads to anxiety and aggressive reactions, making it difficult to function effectively in society. Negative correlations with anxiety (-0.85), aggressiveness (-0.79), and deficit self-esteem (-0.72) confirm that a low level of character harmony is accompanied by difficulties in emotion regulation and social adaptation.

In order to study the psychological aspects of character harmonisation in young people, the relationship between character harmonisation and other psychological characteristics, such as motivation, value orientations and stress level, was analysed. According to the results of the correlation analysis, in the group with a high level of character harmony, there is a positive correlation with value orientations towards self-realisation, development and achievement, as well as with a low level of stress. Instead, in the group with a low level of character harmony, high stress levels and negative correlations with motivation for development and self-realisation were found.

Table 3.
Correlations between the level of character harmonisation and other psychological characteristics

Psychological characteristics	Level of character harmonisation (HCA)	Correlation value (r)
Motivation for development	HCA+	+0.74
Value orientation towards self-realisation	HCA+	+0.80
Stress	HCA-	-0.78
Motivation to achieve	HCA+	+0.70
Self-realisation	HCA+	+0.72

The author of Table 3 is Oleg Khairulin.

The analysis of the correlations between the level of character harmony and other psychological characteristics conducted in this study confirms the importance of personality harmonisation in adolescence for the development of key psychological traits such as motivation, value orientations and stress levels. According to Table 2, in the group of young men with a high level of character harmony (HCA+), there is a positive correlation with such characteristics as motivation for development (+0.74), value orientation towards self-realisation (+0.80), and motivation for achievement (+0.70). This indicates that harmoniously developed young men have a high level of motivation to achieve personal goals, develop their potential and self-realisation. They are developmentally oriented and strive to achieve their ambitions, which is an important aspect of their psychological stability and positive functioning in society. At the same time, these young men have a low level of stress (-0.78), which indicates their ability to effectively cope with life's difficulties and maintain emotional balance.

Instead, the group of young men with low levels of character harmony (HCA-) demonstrates the opposite results, which confirm the negative impact of character disharmony on the development of motivational factors and mental health. Negative correlations with motivation for development (-0.74) and self-realisation (-0.72) indicate a reduced level of intrinsic motivation, which complicates the process of achieving personal development and self-expression. A high level of stress (-0.78) is a sign of a low ability to effectively regulate emotions and adapt to changes in the social environment. Young men with a low level of character harmony may experience significant stress in the process of performing everyday tasks, which leads to the development of psychosomatic problems, increased anxiety and even depression.

In general, the results obtained indicate a close relationship between the level of character harmony and the development of important psychological aspects such as motivation, value orientations, and stress. A high level of character harmony is an important factor in the formation of positive personality traits, such as high motivation for development and self-realisation, as well as the ability to emotional stability under stress. In turn, a low level of character harmony leads to lower motivational levels and high levels of stress, which negatively affects the mental health and social adaptation of young men. This emphasises the need for psycho-correctional measures to maintain character harmony, which is an important component for the successful socialisation and development of young people in modern society.

Conclusions

1. The level of character harmonisation significantly affects the main mental characteristics of young men. A high level of character harmony correlates with increased indicators of emotional stability, social adaptation, self-organisation and self-esteem. This indicates the importance of harmonious personality development for achieving mental health, successful socialisation and adaptation to external conditions. Young people with a high level of character harmonisation have the ability to resolve conflicts constructively, adapt to stressful situations and maintain positive interpersonal relationships.
2. A low level of character harmonisation is associated with negative psychological traits. Young men with a low level of character harmony have higher anxiety, aggressiveness, social maladjustment, and deficient self-esteem. This indicates the need for early detection and correction of character disharmony in young people, as these personal problems can complicate their socialisation and create obstacles to healthy development.
3. Correlation analysis and the construction of personality profiles demonstrate the importance of an individual approach in psychological research and correctional programmes. The use of techniques such as the Harmonious Character Assessment (HCA) and the Personality Trait Questionnaire (PTQ)

allows for a deeper understanding of the relationship between character harmony and other psychological characteristics, which helps to develop effective psycho-correctional and prevention programmes for young people aimed at increasing the level of harmonious character and developing healthy personality traits.

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The Doi Moi dilemma: Balancing economic growth and social justice in Vietnam

Thế tiến thoái lưỡng nan của Đổi mới: Cân bằng tăng trưởng kinh tế và công bằng xã hội ở Việt Nam

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Abstract

This study examines the interplay between economic growth and social progress and justice in Vietnam during the *Doi Moi* (Renovation) era, beginning in 1986. It aims to critically assess how Vietnam has attempted to harmonize economic and social objectives over nearly four decades of transformation. Employing a qualitative methodology grounded in thematic and content analysis of the Communist Party of Vietnam documents, national statistics, and academic literature, the study reveals that Vietnam has achieved notable economic milestones—such as rapid GDP growth, poverty reduction, and rising human development indicators. Simultaneously, the country has expanded social services and advanced education and healthcare access. However, significant challenges persist, including income inequality, regional disparities, unsustainable economic practices, corruption, and limited access to social services for migrants and ethnic minorities. These findings suggest that while Vietnam has made commendable progress, the practical realization of social justice often lags behind policy intent. The study recommends strategic reforms in governance, economic restructuring, and social protection systems, emphasizing that sustainable and inclusive development requires a more integrated and accountable approach to balancing economic and social priorities.

Keywords: *Doi Moi* (Renovation), economic growth, policy reform, social justice, sustainable development, Vietnam.

Tóm Tắt

Nghiên cứu này xem xét mối quan hệ tương tác giữa tăng trưởng kinh tế và tiến bộ xã hội và công lý ở Việt Nam trong thời kỳ Đổi mới, bắt đầu từ năm 1986. Nghiên cứu nhằm mục đích đánh giá một cách phê phán cách Việt Nam đã nỗ lực hài hòa các mục tiêu kinh tế và xã hội trong gần bốn thập kỷ chuyển đổi. Sử dụng phương pháp định tính dựa trên phân tích chủ đề và nội dung các văn bản của Đảng Cộng Sản Việt Nam, số liệu thống kê quốc gia và tài liệu học thuật, nghiên cứu cho thấy Việt Nam đã đạt được những cột mốc kinh tế đáng chú ý - chẳng hạn như tăng trưởng GDP nhanh chóng, giảm nghèo và các chỉ số phát triển con người tăng lên. Đồng thời, đất nước đã mở rộng các dịch vụ xã hội và nâng cao khả năng tiếp cận giáo dục và chăm sóc sức khỏe. Tuy nhiên, vẫn còn những thách thức đáng kể, bao gồm bất bình đẳng thu nhập, chênh lệch giữa các vùng, các hoạt động kinh tế không bền vững, tham nhũng và khả năng tiếp cận hạn chế các dịch vụ xã hội đối với người di cư và các dân tộc thiểu số. Những phát hiện này cho thấy rằng mặc dù Việt Nam đã đạt được những tiến bộ đáng khen ngợi, nhưng việc hiện thực hóa công lý xã hội thường chậm hơn so với mục tiêu chính sách. Nghiên cứu khuyến nghị các cải cách chiến lược trong quản trị, tái cấu trúc kinh tế và hệ thống bảo trợ xã hội, nhấn mạnh rằng phát triển bền vững và toàn diện đòi hỏi một cách tiếp cận tích hợp và có trách nhiệm hơn để cân bằng các ưu tiên kinh tế và xã hội.

Từ khóa: Đổi Mới, tăng trưởng kinh tế, cải cách chính sách, công bằng xã hội, phát triển bền vững, Việt Nam.

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Introduction

Since initiating the *Doi Moi* reforms in 1986, Vietnam has experienced remarkable economic growth, lifting millions out of poverty and positioning itself as one of Southeast Asia's most dynamic economies. However, this progress has come with growing disparities. In 2018, the GINI coefficient reached 0.425 in some regions, underscoring a stark imbalance in income distribution (Oxfam in Vietnam, 2018). This contrast between economic achievement and social inequality highlights a central strategic challenge for Vietnam: how to sustain high growth while ensuring that its benefits are equitably shared across society. This study delves into this critical issue, examining the persistent tension between economic expansion and the realization of social justice in Vietnam.

This issue is global in scope but particularly pressing in the context of Vietnam's transitional economy. Despite decades of reform, uneven development, income inequality, and unequal access to quality education and healthcare remain significant hurdles (Diez, 2016; OECD, 2014; Oxfam in Vietnam, 2018). Without effectively addressing these disparities, economic growth alone may fall short of realizing the inclusive, equitable society envisioned by the Communist Party of Vietnam (CPV) and by Ho Chi Minh himself—who emphasized human liberation and comprehensive human development as core to Vietnam's revolutionary trajectory (Nguyen & Nguyen, 2024).

Since the launch of *Doi Moi*, the CPV has continuously reaffirmed its commitment to building "a prosperous people, a strong country, a democratic, just, and civilized society" (Communist Party of Vietnam, 2021, p. 112). This vision reflects a deliberate attempt to harmonize market-oriented reforms with socialist principles of justice and equity. Vietnam's development path, therefore, is shaped not only by Marxist-Leninist ideology but also by enduring traditional values, including Confucian principles of virtuous governance, moral leadership, and humanistic education (Nguyen, 2023; Pham et al., 2023; Tran, 2024).

The CPV's aspirations are further underscored by its goal of transforming Vietnam into a high-income, socialist-oriented nation by 2045, as articulated during the 13th National Party Congress (Guzikova et al., 2018; Pradhan, 2021). Achieving this ambitious vision requires Vietnam to not only maintain rapid economic growth but also to deepen its commitment to ethical governance, inclusive development, and social justice (Nguyen et al., 2023; Nguyen et al., 2021).

While Vietnam has made substantial gains—such as reducing poverty, boosting GDP, and expanding access to basic services (General Statistics Office of Vietnam, 2023)—formidable challenges persist. These include entrenched income inequality, regional disparities, and underdeveloped institutions of civic responsibility and ethical governance (Le & Nguyen, 2023). Moreover, globalization presents a double-edged sword: it offers economic opportunities while also generating cultural frictions that may undermine traditional values and social cohesion (Nguyen & Nguyen, 2021).

Against this backdrop, this study explores how Vietnam's economic growth strategy has shaped the pursuit of social justice since the inception of *Doi Moi*. It investigates both the notable achievements and the limitations that characterize Vietnam's efforts to align economic development with social equity. Furthermore, it seeks to identify the policy reforms and strategic directions necessary to bridge the gap between growth and justice, ensuring that progress remains inclusive and sustainable.

To address these questions, the paper proceeds in four parts. First, a *Literature Review* outlines theoretical and empirical perspectives on the relationship between economic growth, equity, and sustainability, drawing on both Vietnamese and international scholarship. Second, the *Methodology* section details the qualitative research approach, including content and thematic analysis of CPV documents, national statistics, and academic sources. Third, the *Results and Discussion* section examines the evolving Party discourse and practical outcomes of policy implementation, highlighting achievements, ongoing challenges, and proposed reforms. Finally, the *Conclusion* reflects on the broader implications of Vietnam's experience and outlines pathways for future policy and research.

Literature Review

Theoretical Frameworks

The interplay between economic growth and social justice in Vietnam has been a focal point of both academic and policy discourse since the launch of the *Doi Moi* (Renovation) reforms in 1986. These reforms initiated Vietnam's transition toward a socialist-oriented market economy, raising questions about how to reconcile market dynamics with socialist ideals.

A central theoretical contribution comes from N. T. Tran (2010), who provides a foundational analysis of the period 2010–2020. He outlines strategic measures such as institutional realignment and inclusive policymaking to balance economic growth with social fairness. Tran's integration of abstract theory with practical policy solutions offers a roadmap for aligning development with equity.

T. T. M. Tran (2024) takes a philosophical approach, revisiting the ideological foundations of Vietnam's development model. Her work traces Ho Chi Minh's synthesis of Confucian values and Marxist-Leninist principles, emphasizing ethical leadership and people-centered governance as enduring features of Vietnam's socio-political ethos. These theoretical frameworks collectively inform the normative basis of Vietnam's developmental aspirations.

Economic Growth and Social Equity

Vietnam's rapid economic growth has coincided with persistent inequalities in income distribution, regional development, and social service access. A growing body of literature examines these issues within the broader context of Vietnam's transition economy.

Le and Nguyen (2023) provide a recent and comprehensive analysis of social justice under *Doi Moi*. They argue that justice must be a precondition—not merely a by-product—of economic growth. Their study documents advances such as near-universal health insurance and rights-based social assistance, while also highlighting enduring challenges including regional disparities and exclusion of marginalized groups. Their proposals emphasize labor market reform, macroeconomic coordination, and international cooperation.

Oxfam in Vietnam, 2018, from an international perspective, Malesky and London (2014) acknowledge Vietnam's dramatic transformation but express concern about the long-term inclusivity of this growth. Similarly, Diez (2016) praises Vietnam's poverty reduction and economic expansion while cautioning that structural issues, such as corruption and unequal access to services, continue to undermine social equity.

Oxfam in Vietnam (2018) reports further contextualize these trends, noting that inequality has increased, with the GINI coefficient reaching 0.425 in some regions. These findings stress the need for economic policies that actively counterbalance market-driven disparities.

Governance and Institutional Factors

Governance quality and institutional reform are central to Vietnam's development trajectory. Several scholars emphasize the state's role in shaping equitable and sustainable outcomes, particularly in the context of corruption and policy implementation.

Diez (2016) identifies corruption as a critical barrier to inclusive development, noting that it impairs both economic efficiency and social justice. This concern is echoed by Vu and Cao (2024), who explore Vietnam's anti-corruption efforts under *Doi Moi*. They argue that while symbolic measures exist, many reforms lack structural depth. Cultural norms such as gift-giving further complicate reform implementation, signaling a need for more systemic approaches.

Pradhan (2021) evaluates Vietnam's performance during the 2016–2021 period, calling for a calibrated development strategy that sustains economic momentum without sacrificing human welfare. He stresses that the success of such a strategy hinges on the quality of governance and institutional capacity.

Sustainable Development and Environmental Justice

The concept of sustainable development has gained increasing prominence in Vietnamese and international analyses of post-*Doi Moi* growth. A central theme in this literature is the need to integrate environmental sustainability and social justice into economic planning.

Guzikova et al. (2018) introduce the "sustainable development triangle," linking economic growth, social equity, and environmental stewardship. Their comparative framework aligns with Vietnam's stated development principles, reinforcing that sustainability requires balance across all three dimensions.

Fan et al. (2020) explore the Formosa Ha Tinh Steel disaster as a case study in environmental injustice. They argue that state-subsidized industrialization prioritized economic output over ecological and social well-being. Their emphasis on transnational justice networks and civil society activism underscores the rising influence of non-state actors in promoting sustainable development.

D. H. Nguyen et al. (2025) provide empirical support for integrating environmental and economic goals through green finance. Their spatial econometric study across all 63 provinces finds that green credit positively correlates with sustainable development outcomes. They advocate for clearer regulatory frameworks and expanded access to green finance, especially in underserved regions.

Can and Dang (2024) assess Vietnam's shifting growth paradigm, noting that traditional drivers—such as low-cost labor and foreign direct investment—are losing traction. They propose a new growth model based on green development, innovation, and inclusive services, consistent with Vietnam's 2021–2030 development strategy.

Research Gaps

This body of literature presents a robust, multidimensional understanding of Vietnam's development under *Doi Moi*. The works reviewed span theoretical, empirical, and normative domains, revealing the complex interdependence of growth, equity, governance, and sustainability. Vietnamese scholars often emphasize the CPV's central role in maintaining balance between market liberalization and socialist values, while international voices highlight institutional quality and policy implementation.

However, notable gaps remain. Environmental justice, though addressed in works like Fan et al. (2020) and D. H. Nguyen et al. (2025), is still insufficiently integrated into mainstream economic policy analysis. Furthermore, while many studies highlight policy innovation, practical implementation continues to lag, particularly in marginalized areas.

Building upon this literature, the current study investigates how contemporary Vietnamese policy frameworks operationalize the integration of economic and social goals. It examines whether recent instruments reflect the values espoused by both policy-oriented scholars like Le and Nguyen (2023) and foundational ideologues such as Ho Chi Minh, as interpreted by T. T. M. Tran (2024). In doing so, it contributes to ongoing debates on how Vietnam can pursue high-quality, inclusive development while remaining anchored in its ethical and ideological traditions.

Methodology

This study employs a qualitative research design grounded in document analysis to explore the complex interplay between economic growth and social justice in Vietnam's development trajectory since the *Doi Moi* reform of 1986. The qualitative approach was chosen for its suitability in capturing the nuanced and context-specific processes underpinning Vietnam's socio-economic transformation. It allows for the critical interpretation of textual data, facilitating the identification of both overt and latent policy trends and ideological undercurrents. This design aligns with the study's objective to evaluate both the conceptual framing and practical implementation of Vietnam's economic and social development strategies.

The research does not involve human participants but instead focuses on an extensive review and interpretation of secondary data sources. These include official Party documents from the 6th to the 13th Congresses of the Communist Party of Vietnam (1986, 1991, 1996, 2001, 2011, 2016, 2021) , statistical data from the General Statistics Office of Vietnam (2019, 2023), and national development strategies.

Additional materials comprise academic articles, government reports, international development assessments (e.g., OECD (2014); Oxfam in Vietnam (2018)), and recent scholarly works by both Vietnamese and foreign researchers. Selection criteria for these materials prioritized relevance to the *Doi Moi* period, the credibility of the sources, and the extent to which they addressed the intersection of economic growth and social equity.

The primary tools used in the research are qualitative data analysis techniques, particularly thematic coding and content analysis. NVivo software was used to support the coding process and facilitate thematic clustering across large volumes of text. This ensured consistency and rigor in identifying recurrent themes such as state intervention, poverty reduction, income inequality, environmental sustainability, and public sector reform. These thematic clusters were cross-referenced with economic indicators such as GDP growth rates, GINI coefficients, and Human Development Index (HDI) data to triangulate insights and ensure analytical coherence.

The research procedure followed a systematic process. First, a comprehensive body of relevant literature and policy documents was collected. Second, the texts were read closely to extract themes and policy shifts over time. Third, a comparative analysis was conducted to map the evolution of Party perspectives and their translation into concrete policy measures. Lastly, this evidence was synthesized to evaluate the gap between policy intentions and practical outcomes, as well as the implications for Vietnam's sustainable development.

In terms of data analysis, the study utilized interpretative methods grounded in political economy and social justice theory. Key metrics such as poverty rates, HDI rankings, and labor force data were analyzed in conjunction with qualitative findings to assess the alignment between economic growth and social progress. This triangulation ensured a robust, multidimensional understanding of Vietnam's development path, enabling conclusions that are both analytically rich and grounded in empirical data.

As the research did not involve human or animal subjects, formal ethical approval was not required. However, all sources used were publicly available and properly cited, ensuring adherence to academic integrity standards. Moreover, the study was conducted in alignment with ethical norms in qualitative research, particularly regarding the respectful representation of diverse perspectives and the avoidance of ideological bias.

Results and Discussion

Evolving Party Perspectives on Economic Growth and Social Justice Since *Doi Moi*

Before 1986, under challenging conditions due to socio-economic crises, many objectives related to social progress could not be achieved. With strong determination for innovation, the 6th Party Congress elevated social issues to the level of "social policy," equating them with economic policy, and affirmed: "The level of economic development is the material condition to implement social policy, but social objectives are the goals of economic activities" (Communist Party of Vietnam, 1986, p. 86). By the 7th Party Congress (1991), the Party considered effective social policy implementation not only as a goal but also as a "driving force for economic development" (Communist Party of Vietnam, 1991, p. 73). The 8th Party Congress (1996) introduced a new understanding of this relationship: "Economic growth must be closely linked to social progress and justice at every step and throughout the development process. Justice must be reflected both in the rational distribution of production materials and in the distribution of production outcomes, ensuring conditions for everyone to have opportunities for personal development and the effective use of their capacities" (Communist Party of Vietnam, 1996, p. 113). This means each step of economic growth must be immediately linked to advancements in social progress and justice, and conversely, each step forward in social progress and justice must generate motivation for economic growth.

At the 9th Party Congress (2001), the Party adopted the policy of "economic growth coupled with social progress, justice, and environmental protection" (Communist Party of Vietnam, 2001, p. 162), recognizing that failing to protect the environment would undermine both economic and social development goals. Additionally, living in a healthy environment is considered a criterion of social security policies. By the 10th Party Congress (2006), the Party emphasized that achieving GDP targets should align with Human Development Index (HDI) targets. Distribution of benefits should be based on capital contributions and other resources to production and business, rather than merely on "labor days" as before Renovation. The

11th Party Congress document set specific targets for social progress: "By 2020, the Human Development Index (HDI) will reach the world's upper-middle group... average life expectancy will reach 75 years; the poverty rate will reduce annually by an average of 1.5-2%; social welfare, social security, and public healthcare will be guaranteed" (Communist Party of Vietnam, 2011, pp. 104-110).

By the 12th Party Congress (2016), the Party identified socio-economic development as the central task, placing social issues equally with economic issues. Most recently, the 13th Party Congress documents parallel economic objectives (Vietnam to surpass lower-middle-income status by 2025, become an upper-middle-income country by 2030, and a high-income country by 2045) with tasks such as "effectively implementing social policies, ensuring social security and welfare, human security, creating substantial transformations in social development management, implementing social progress and justice, and improving the quality of life and happiness of the people" (Communist Party of Vietnam, 2021, p. 47). Overall, the close integration of economic growth with social progress and justice has been a consistent ideology of the Communist Party of Vietnam throughout the Renovation period. It is identified as one of the ten major relationships reflecting the law of socialist development in Vietnam.

Evaluation of Practical Implementation Outcomes

Notable Achievements in Economic and Social Development

Regarding economic growth, by realizing state policies and laws in the economic sector, Vietnam achieved an average annual GDP growth rate of 7.6% during the period 1991-2000 (higher than the global growth rate of 3.2% and the average growth rate of developing countries at 6%). Thanks to this relatively high growth rate, Vietnam had largely emerged from its socio-economic crisis by 1996. Between 2001 and 2010, Vietnam's average annual GDP growth rate was 7.26% (compared to the global growth rate of 3.28% and the developing countries' rate of 5.56%). By 2010, Vietnam had moved out of the group of least developed countries into the category of lower-middle-income developing nations. Recently, with GDP growth rates of 7.47% (2018), 7.36% (2019), 2.87% (2020), 2.56% (2021), 8.02% (2022) (General Statistics Office of Vietnam, 2023, p. 10), and 5.05% in 2023, Vietnam ranks among the fastest-growing economies in the region and the world. Consequently, per capita GDP in Vietnam has consistently increased: from $2,570 in 2018; $2,714 in 2019; $3,561 in 2020; $3,717 in 2021; $4,109 in 2022; to $4,284 in 2023. Although income levels remain modest, a low inflation rate (3.25% in 2023) ensures relatively high purchasing power, maintaining a stable quality of life for most citizens.

Parallel to economic achievements, Vietnam has also made significant progress in social justice and development. Since the 8th Party Congress (1996), the Communist Party of Vietnam has clearly identified "social justice" as a defining characteristic of socialism in Vietnam, setting it as an essential goal. In economics, the state has recognized a multi-sector economy with various forms of ownership and implemented diverse distribution methods. In education, universal lower-secondary education was achieved by 2010, and policies supporting disadvantaged and poor students have provided educational opportunities for youth. Welfare efforts for those who have contributed significantly to the nation have continually improved, and social welfare funds have consistently expanded. Notably, Vietnam has effectively implemented poverty reduction programs. By 2008, Vietnam had achieved most Millennium Development Goals set for 2015. Since 2016, Vietnam has adopted a multidimensional poverty reduction approach aligned with global trends. According to documents from the 13th Party Congress, the multidimensional poverty rate in 2020 was below 3% (Communist Party of Vietnam, 2021, p. 65). Reflecting these notable achievements, an international researcher commented: "Viet Nam achieved sustained growth over the past decade accompanied by impressive progress in poverty reduction. These achievements are largely attributed to the *Doi Moi* economic reform process, initiated in 1986, which launched a series of structural transformations that encouraged private sector development and foreign investment, moving towards a decentralised and market-oriented economy. Sustained economic growth improved the overall living standards of the majority of the population in terms of income and health status, with many Vietnamese entering the middle class" (OECD, 2014, p. 43). To promote sustainable poverty reduction, the state has made considerable efforts in job creation. The unemployment rate decreased from 6.9% in 2001 to 2.29% in 2016, further reducing to 2.22% in 2017, 2.19% in 2018, and 2.17% in 2019. However, the COVID-19 pandemic and global supply chain disruptions increased unemployment rates to 2.48% in 2020, 3.20% in 2021, and 2.34% in 2022 (General Statistics Office of Vietnam, 2023, p. 17).

In pursuing social objectives, the Vietnamese government has ensured the provision of essential public services, developed a diversified social security system, and significantly expanded insurance schemes to support people in times of risk. The government has also formulated a national strategy to enhance public health. To ensure universal access to healthcare, the state provides universal health insurance and subsidizes health insurance premiums for the poor; children under six years of age receive free medical care.

A crucial indicator demonstrating the implementation of social policies is the Human Development Index (HDI). According to the United Nations Development Program (UNDP) in Vietnam, Vietnam's HDI has steadily and continuously increased over several decades: from 0.48 in 1990 to 0.647 in 1995 and 0.715 in 2015. According to Vietnam's General Statistics Office, recent HDI values are as follows: 0.693 (2018); 0.703 (2019); 0.706 (2020); 0.726 (2021); and 0.737 (2022) (General Statistics Office of Vietnam, 2023, p. 981). With these achievements, Vietnam has entered the group of countries with high HDI globally, indicating that its socio-economic development significantly supports human development, social progress, and justice.

Persistent Challenges and Structural Limitations

Despite relatively high economic growth, Vietnam's growth rate remains below its potential and is unsustainable. GDP growth in 2023 was only 5.05%, compared to 8.02% in 2022. The competitiveness of the Vietnamese economy has improved slowly. Vietnam's economic growth largely relies on extensive growth—dependent on increased capital investment and resource exploitation rather than human resource quality improvements. According to the General Statistics Office, Vietnam's GDP in 2023 reached approximately USD 430 billion, ranking 34th globally, despite being the world's 15th most populous country. The implementation of the three key focuses of economic restructuring (public investment, banking systems, state-owned enterprises) has not met expectations, resulting in modest productivity, quality, efficiency, and competitiveness.

Regarding social objectives, per capita income in Vietnam remains relatively low. Although the national poverty rate is low, "poverty reduction results are not sustainable. Poverty and near-poverty rates in remote areas, especially among ethnic minorities, remain high. In some districts and communes, it reaches up to 50%, and mechanisms to protect legitimate rights for laborers in these areas remain inadequate" (Communist Party of Vietnam, 2016, p. 256). Oxfam in Vietnam (2018, p. 13) also noted that "poverty increasingly concentrates among ethnic minority groups". Despite numerous state policies addressing these issues, their effectiveness has been limited.

Another significant issue with Vietnam's growth is income inequality. According to the General Statistics Office of Vietnam, the GINI coefficient (a measure of income inequality among populations) has varied over recent years: 0.425 (2018), 0.423 (2019), 0.375 (2020), 0.374 (2021), and 0.375 (2022). However, regions with high poverty rates, such as the Northern Midlands and mountainous areas and the Central Highlands, consistently report the highest GINI coefficients (0.408 and 0.399 respectively). Significant disparities exist in income and living standards among ethnic groups, with Kinh and Hoa ethnic groups generally enjoying higher living standards. However, economic inequality is only one facet of the broader issue. Oxfam in Vietnam emphasized that "inequalities of voice and opportunity are much more worrying, especially for the poor and people in rural, mountainous and island areas." (2018, p. 14). One researcher noted, "while the richest and most privileged are able to influence policy in their favor, the poorest and most marginalized citizens are unable to make their voices heard, trapping them at the bottom of the economic and social ladder." (Nguyen, 2017, p. 9).

Another notable issue is the increased migration from rural to urban areas due to diminishing agricultural land, lack of employment, and low-income opportunities in rural areas. According to the 2019 national census, of Vietnam's 88.4 million residents aged five and older, approximately 6.5 million people, or 7.3%, had migrated (General Statistics Office of Vietnam, 2019, p. 100). These statistics exclude short-term or seasonal migrants not captured in national data. Vietnam has yet to develop specific and consistent policies to regulate migration, and government attention to spontaneous migrants remains inadequate. Current household registration policies restrict migrants' citizenship rights. Excluded from local planning processes, "many migrants remain impoverished and struggle to access social services. Often, migrants are women with limited knowledge about their rights, working under poor conditions with low wages, or eventually becoming trafficking victims or engaging in prostitution" (Diez, 2016). The disparity in social welfare benefits between locals and migrants contradicts Vietnam's objective of building a fair and

equitable society. Furthermore, insufficient compensation for farmers whose land is allocated to industrial or infrastructure projects highlights shortcomings in implementing social justice.

Corruption remains Vietnam's most pressing issue. Transparency International (TI) reports show Vietnam's Corruption Perceptions Index (CPI) as 36/100 in 2020, 39/100 in 2021, 42/100 in 2022, and 41/100 in 2023, reflecting a decline compared to 2022 and ranking Vietnam 83rd out of 180 countries globally. Public sector corruption in Vietnam remains severe. The existence of "backyard enterprises" owned by government officials raises concerns about crony capitalism. A researcher argued, "crony capitalism remains a prominent feature of Vietnam's economy" (Diez, 2016). Evidence supporting this includes numerous cases where prosecuting illegal activities involving businesspeople results in related corruption charges against public officials.

Some Solutions to Enhance the Relationship Between Economic Growth and Social Progress and Justice in Vietnam

To better address this crucial relationship and foster sustainable development, Vietnam needs to implement a comprehensive set of solutions.

Firstly, it is essential to raise awareness throughout the entire political system, particularly among leadership and management officials and policymakers responsible for policy planning and oversight, regarding the necessity of linking economic and social objectives. There must be firm opposition to the pursuit of profit at all costs or populist policies that attempt to resolve social issues beyond the economic capabilities, as any imbalance leads to negative outcomes.

Secondly, a comprehensive long-term strategy is required to address this relationship systematically. Ultimately, linking economic goals with social objectives is aimed at establishing a sustainable development model, which must be a consistent and long-term strategy. Therefore, a comprehensive strategy should guide actors in choosing appropriate actions proactively. While allocating greater investment to key economic regions to drive national economic growth is necessary, attention must also be paid to remote areas and regions inhabited by ethnic minorities.

Thirdly, the process of restructuring the economy should be accelerated, shifting gradually from an extensive growth model to one increasingly focused on intensive development. Changing the economic model fundamentally involves enhancing the "cultural content" of the economy, which means improving human resource quality, refining production processes, and applying science and technology to create high-value-added products. This enriched material wealth serves as the foundation for achieving social justice, providing workers with appropriate income to enhance their material and spiritual lives.

Fourthly, institutional improvements and the refinement of the legal framework must be enhanced. In the immediate term, the policies of the 13th Party Congress regarding the tight integration between economic growth and the implementation of social progress and justice should be institutionalized into state policies and laws. It is necessary to eliminate gaps in mechanisms and policies to ensure the economy operates according to objective market rules. At this stage, the state must ensure equity among different economic sectors, facilitating the formation and development of major private economic corporations. Special measures must be effectively implemented to "appropriately care for disadvantaged and vulnerable social groups" (Communist Party of Vietnam, 2021, p. 135).

Fifthly, Vietnam must simultaneously enhance the state's managerial and regulatory role and actively promote the socialization of essential services. With a market economy, especially one in its early stages like Vietnam's, the "invisible hand" of the market will not automatically steer towards social progress and justice; instead, it may hinder these objectives and generate complex socio-economic issues. Thus, enhancing state regulatory capabilities is essential to mitigate negative market impacts and ensure public welfare. The 12th Party Congress documents (2016) affirmed the policy: "The state utilizes institutions, resources, regulatory tools, and distribution and redistribution policies to develop culture, implement democracy, social progress, and justice, improve all aspects of people's lives, and reduce the rich-poor gap" (Communist Party of Vietnam, 2016, p. 269). However, regulation should be through appropriate taxation policies and sanctions, not through heavy-handed state intervention in the market.

Sixthly, the state must continue to expand and enhance the multi-layered social security system. Although Vietnam's social security system has increasingly demonstrated its significant role in socio-economic development and stability, further expansion is necessary. A diversified social security system will promote consensus, equality, social progress, and justice.

Seventhly, it is crucial to build an honest government and maintain zero tolerance toward corruption, "interest groups," and illegal enrichment. Corruption and illicit enrichment harm healthy economic growth and generate social injustice; thus, their elimination must be decisive. Experience shows that no institution or policy, regardless of its quality or completeness, can be effective without an honest cadre of officials and civil servants. Therefore, strengthening discipline and building mechanisms for power oversight in public service, from central to local levels, is necessary to enhance the quality of public services.

Conclusions

This study set out to investigate the evolving relationship between economic growth and social progress and justice in Vietnam under the transformative framework of the *Doi Moi* reforms initiated in 1986. The central research question focused on how effectively Vietnam has balanced these two foundational objectives over nearly four decades of transition toward a socialist-oriented market economy. The analysis reveals a complex picture: while Vietnam has recorded impressive economic achievements—marked by sustained GDP growth, increased per capita income, and deep integration into the global economy—it continues to grapple with persistent social disparities that challenge the inclusiveness and sustainability of its development model.

Empirical evidence shows that Vietnam has made significant headway in reducing poverty, expanding access to education and healthcare, and improving social welfare indicators. Its Human Development Index has risen steadily, and the multidimensional poverty rate has declined over time. Nonetheless, these gains coexist with enduring structural barriers. Rising income inequality, ethnic and regional disparities, rural and migrant marginalization, and weak institutional capacity—particularly in combating corruption—pose serious obstacles to the realization of equitable development. Despite the Communist Party of Vietnam's consistent rhetorical and strategic emphasis on social justice, the gap between policy commitments and implementation outcomes remains a defining feature of Vietnam's developmental landscape.

The broader implications of these findings underscore that economic indicators alone are insufficient for evaluating national progress. Sustainable development requires embedded mechanisms of social equity, inclusive governance, and environmental responsibility. This aligns with theoretical perspectives that view social justice not as a derivative of economic growth, but as a prerequisite for its legitimacy and long-term viability. Vietnam's experience thus provides a critical lens through which to examine the tension between state-led growth and distributive justice—serving both as a model of dynamic reform and as a cautionary example of uneven implementation.

The study also acknowledges its limitations. Its reliance on secondary data and qualitative methods, while useful for capturing conceptual depth and longitudinal trends, may not fully reflect the lived experiences or localized variations in policy effectiveness. More granular, field-based research could enhance understanding of how policies are perceived and enacted at the community level. Additionally, the study's broad scope may overlook important sector-specific dynamics that deserve closer scrutiny.

Looking forward, future research should investigate how Vietnam can better align institutional reforms, green growth strategies, and social protection mechanisms to close the persistent gap between economic advancement and social equity. In particular, the evolving roles of civil society, non-state actors, and international partnerships merit deeper exploration in shaping inclusive and participatory development. As Vietnam confronts emerging challenges such as climate change and digital transformation, integrating these dimensions into national policy frameworks will be critical for ensuring that growth remains both resilient and just.

In conclusion, this study offers a comprehensive assessment of Vietnam's post-*Doi Moi* development, highlighting both its successes and the persistent challenges in balancing economic growth with social justice. Its key contribution lies in providing a nuanced analysis of the gap between policy commitments and practical outcomes, offering valuable insights for refining development strategies not only in Vietnam but also in other transition economies striving for inclusive and sustainable growth. As Vietnam aspires to

become a high-income, socialist-oriented nation by mid-century, its experience offers critical reflections on how states can navigate the complex and evolving balance between growth and justice in an increasingly globalized and uncertain world.

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Development of creativity in future teachers of musical disciplines

Розвиток креативності майбутнього викладача музичних дисциплін

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Abstract

The article highlights methodological innovations in the ascertaining and formative stages of research The purpose of the study is to evaluate the outcomes of an experimental study future music teachers. A specially designed choice situation serves as a pedagogical. The pedagogical tool for developing creativity in future music teachers of artistic disciplines used in this study is a specially designed choice situation. The means of achieving the desired results included diagnostics of students' initial creativity levels, conducting an experimental test based on a system of creative tasks developed from the choice situation classifier. Statistical analysis confirmed the effectiveness of the proposed methodology. The criteria for monitoring the development of creativity in future educators were established, and the effectiveness of the methodological innovations was evaluated through tests comparing results at the initial and formative stages of the study. Received positive changes in the levels of creativity formation of future teachers of musical disciplines according to all established criteria. The system of students' creative personal qualities that contribute to the formation of their readiness for professional activity was identified and expanded.

Keywords: creativity, creative abilities, development methods, criteria and levels of development, music teacher.

Анотація

У статті висвітлено методичні інновації констатувального та формувального етапів дослідження. Мета статті – оцінити результати експериментального дослідження щодо розвитку креативності майбутніх викладачів музичних дисциплін. Педагогічним засобом розвитку креативності майбутніх фахівців у дослідженні виступає спеціально спроєктована ситуація вибору. Засобами досягнення результату з'явилися діагностика вихідного рівня креативності студентів, проведення експериментальної перевірки на базі створеної системи творчих завдань, заснованої на класифікаторі ситуації вибору. Ефективність запропонованої методики підтверджена результатами статистичної обробки експериментальних даних. Одержано позитивні зміни у рівнях сформованості креативності майбутніх викладачів музичних дисциплін за всіма встановленими критеріями. Доповнено систему креативних особистісних якостей студентів, що сприяють формуванню їх готовності до професійної діяльності.

Ключові слова: креативність, творчі здібності, умови та методика формування, критерії та рівні сформованості, викладач музичних дисциплін.

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Introduction

Human creative activity is an essential part of the economic, social, and cultural structures of society. Creatively active individuals are considered a national treasure. The more effectively an individual's creativity is developed, the more dynamically society as a whole evolves. Several factors determine the importance of fostering individual creativity: the globalization of living spaces, advancements in science and technology, the rapid pace of updating scientific knowledge, and the widespread use of modern information and communication technologies in everyday life (Bodak et al., 2021). This makes the problem of fostering the creativity of each person a priority. The effectiveness of the applied methodological innovations was assessed through a series of tests comparing the results at the ascertaining and formative stages of the study.

Theoretical basis or literature review

The problem of the development of individual creativity at the present stage has been studied by Ukrainian and foreign researchers: Ivanchenko, 2017; Voitsekhivska et al., 2013; Gorban, 2018; Grinenko, 2008; Derevyana, 2009; Drozdova, 2008; Dunaeva, 2008; Ilyakhova, 2018; Epstein, 2003; Karpenko, 2016; Molyako, 2013; Pavlenko, 2016; Pavlyuk, 2007; Poznyak, 2013; Renzulli, 2012; Posluszna, 2017; Rebriy, 2012; Sahlberg, 2009; Simonton, 2017; Sysoeva, 2015; Tkachenko, 2014; Frytsiuk, 2018; Furman & Shandruk, 2013; Hamm, 2012; Yaochen, 2013; Shevchenko & Brodsky, 2013, etc.

The analysis of scholars' interpretations allows us to conclude that creativity is a personal quality based on the potential capabilities of each individual, the actualization of an unconscious need to be a unique personality – free, yet connected to the collective through the products of their creativity – harmoniously combining individual and socially significant interests. The works of scientists focus on exploring ways to develop individual creativity and methods for organizing creative activity, as well as addressing the development of creative abilities in educational activities. It is emphasized that creativity, as the optimal development of all available individual potentials and a general universal ability, is manifested and realized in the creative process. In the studies of scientists who reveal the features of the creative process of a teacher-musician (Aksinina, 2011; Frytsiuk, 2018; Shevchenko & Brodsky, 2013, etc.), the importance of thinking outside the box, responding quickly and flexibly to situations that are constantly changing in the process of musical activity is emphasized – making adequate decisions in a choice situation, finding unconventional ways to solve creative tasks, and unconventional approaches to the embodiment of artistic images. The issue of using the potential potential of choice in the musical educational activity of adolescent students was considered by Pan Qianyi, Regina Savchenko & Yuliia Savchenko-Shlapak, (2021). However, the problem of purposeful use of choice in musical educational activity as an active development of creativity of future specialists was not the subject of independent research. In higher education institutions, as practice shows, the development of creativity of a future teacher of musical disciplines occurs spontaneously, without systematic organization, as evidenced by Savchenko, Savchenko, Sokhan (2024).

The scientific novelty of the study lies in an attempt to fill the gap in research between the need for high-quality training of a teacher of music disciplines with a high level of creativity development and the lack of methodological developments for its formation in the system of higher music and pedagogical education. Also, the insufficient study of the possibilities of music disciplines and pedagogical conditions for their implementation in the formation of the creativity of a future specialist. The potential of the choice situation has been identified and a model for the formation of creativity of future teachers of music disciplines has been developed based on their use in educational and musical activities; criteria and indicators of the formation of creativity have been determined; pedagogical conditions for the productive use of the choice situation as a means of forming creativity of future specialists have been substantiated and experimentally confirmed.

Methodology

As a means of developing the creativity of future specialists, a choice situation in educational and musical activities was chosen. On its basis, the entire complex of the implementation system is built, where the choice situation is the core of the system, its central link. The methods and techniques of implementation are didactic games, theater technologies, role modeling, compiling repertoire lists, psychological and

pedagogical training on the development of creative qualities, musical works, etc. The forms of implementation of the process of developing students' creativity based on the use of the choice situation in educational and musical activities were individual, pair, group classes. The individual form of solving tasks by students to choose from without the participation of other subjects – classmates, etc. In the pair form, there is a compromise choice of participants in the situation; at the same time, everyone who participates in the pair creative process makes their contribution, and the chosen solution is defended together. The group form is characterized by a collective solution to the problem, discussion of different options for the task, development of the ability to negotiate, the ability to communicate.

Methodological innovations included an author's lecture course on the topic of "Modern Trends in the Development of Music Education"; psychological and pedagogical training on the development of creative qualities of the individual; a competition of self-studied works "Music for Children"; diagnostic materials; a classifier of choice situations; recommendations for the teacher and the student; means of checking and assessing the level of creativity development.

The methodology for forming the creativity of future teachers of musical disciplines consists of three stages; each of which solves its own tasks for the development of students' creativity, which is reflected in the steps – situations of choice. The first stage is the initial one. The tasks of the stage include preparing students for action in the conditions of a situation of choosing an educational task and developing such creative qualities: interest, the ability to see and identify problems, imagination and fantasy, a positive attitude towards creative activity, the desire to make an independent choice. Steps-situations of choosing an educational task: information, musical material, form of its presentation, partner, style of communication with the audience, performing means, interpretation. The teacher's action at this stage is pedagogical support for the student. The second stage is the main one. The task of this stage was to actualize the students' independent actions in a situation of choice and develop such creative qualities as: purposefulness, susceptibility to new ideas, independence, having one's own opinion (argumentation of choice), readiness to choose. Steps-situations of choosing: educational task, volume of work, level of complexity, form of performance, partner, method of presenting results. The choice of material, form of presentation, style of communication, performing means and interpretation remain among the previous tasks, but their implementation requires students to make some independent decisions. At this stage, the teacher acts as a consultant, and students begin to independently manifest themselves in a situation of choice. The third stage is the final one. The tasks of the stage were the independent actions of students in a situation of choice and the development of such creative qualities as: initiative, focus on the result of educational and musical activity – the creation of a personal creative product, the presence of one's own opinion, the absence of categorical judgments, readiness and ability to choose, responsibility for making a decision. Steps-situations of choice: partner (partners), goals of the activity, topic, form of performance, the content of the activity, methods, the volume of work and method of presenting results, level of complexity, nature of activity and its types, duration of performance, form of presentation of material, style of communication, means of performance, interpretation, value choice. The teacher acts at this stage as an observer. The peculiarity of this stage is to provide students with complete freedom of action in a situation of choice and to identify their manifestations of responsibility for making a decision.

The assessment of students' creative qualities was conducted using the expert evaluation method by teachers of music disciplines, utilizing a table listing 24 creative qualities (Table 1).

Table 1.
Creative qualities of future teachers of music disciplines

№	Creative qualities of personality	Number of mentions in questionnaires
1.	Determination	65
2.	Interest	63
3.	Imagination	63
4.	Independence	60
5.	Readiness to choose	59
6.	Receptiveness to new ideas and knowledge	58
7.	Ability to associate	58
8.	Responsibility for the chosen decision	55
9.	Having one's own opinion	52
10.	Presence of a creative product	50
11.	Flexibility	48

12.	Predictive ability	4
13.	Problem perception	46
14.	Risk-taking tendency	44
15.	Initiative	44
16.	Creative attitude toward learning	42
17.	Originality	42
18.	Sense of humor	41
19.	Emotionality, empathy	41
20.	Adaptability	40
21.	Creative thinking	38
22.	Ingenuity	36
23.	Intuition	36
24.	Dialogical nature, openness	34

In addition to the qualities listed in the table, expert teachers also noted the following traits in students: curiosity – 33, emotional openness – 32, imagination – 30, a sense of novelty and uniqueness – 29, the ability to overcome stereotypes – 28, inspiration – 25, daydreaming – 22, originality – 17, independence – 16, the ability to apply knowledge and skills in new situations – 16, a tendency toward creative doubt – 15, modesty – 10, contemplation – 7, and insight – 3.

Experimental testing of the proposed methodology lasted from 2022-2024. The results of the study were implemented in the educational process of the Faculty of Arts of the Mykhailo Dragomanov Ukrainian State University, Kryvyi Rih State Pedagogical University and Melitopol State University. The total number of participants in the experiment at all stages (confirmatory, formative, final) was 207 students.

The method of ascertaining tests was used to verify the results of the implementation of the developed methodology for the formation of creativity of future teachers of musical disciplines (Pavlenko, 2016).

Results and discussion

The ascertaining stage of the experiment determined the initial state of the development of students' creativity in educational and musical activities. Diagnostic materials in the study are presented in the form of the following methods: pedagogical observation, questionnaires (four author's questionnaires), testing, expert assessment method, competent assessment method, project method, etc. Based on the analysis of a significant number of choice situations (250 cases) and the personal pedagogical experience of Savchenko R., a classifier for educational activity choice situations was developed. This classifier is presented as a table containing components that reveal the content of the choice situation in the educational activity of future teachers of music disciplines. (see Table 2).

Table 2.
Classifier of choice situations

Classification features	Types of choice situations	Types of choice situations
Freedom of choice	1. A situation with complete freedom of choice. 2. A situation with limited freedom of choice.	Situations of choice: - Partner(s); - Activity goals; - Educational trajectory; - Topics; - Forms of implementation; - Content of the activity; - Methods; - Volume of work; - Method of presenting the results; - Level of complexity; - Nature of the activity (reproductive, partly - search, creative); - Types of activity (communicative, organizational, research, constructive, executive, reflective); - Duration of the activity.
Mandatory performance	1. Situation of necessary and mandatory choice. 2. Situation of optional (optional) choice.	
Awareness of choice	1. A situation of random choice. 2. A situation of intuitive choice. 3. A situation of conscious choice.	
Degree of responsibility for results	1. A situation of irresponsible choice. 2. A situation of responsible choice.	
Form of organization of the pedagogical process	1. Choice situation in classroom lessons. 2. Choice situation in the course of independent work.	

	3. Choice situation in educational and production practice.	
Willingness to choose	1. Independent choice situation. 2. Partially independent choice situation. 3. Non-independent choice situation.	
Quantitative composition of selection participants	1. Individual choice. 2. Group choice. 3. Collective choice.	
Time frame	1. Operational choice situation. 2. Tactical choice situation. 3. Strategic choice situation	

The classifier is the central link of the methodological complex, which allows to consistently build the process of developing creative personal qualities of students through situations of choice in educational activities. Diagnostic tools aimed at diagnosing the existing levels of formation of creativity of future teachers of musical disciplines included methods of observation, questionnaires, testing, a method of creating creative products including situations of real choice; situations of choosing educational tasks of different levels; situations of choosing according to certain criteria; situations of choosing an educational goal by the degree of orientation; situations of choosing according to the motivation for achieving the goal. The connection between the development of creative qualities of the personality and the situation of choice in educational and musical activities was traced.

The results of the ascertaining stage of diagnostics showed that the general level of development of creativity of future teachers of musical disciplines does not meet the requirements established by regulatory documents. This is manifested, in particular, in the passive attitude of students to choosing a non-standard situation; weak expressiveness of goals and interest in educational activities; the undeveloped sphere of cognitive personal qualities; indifferent attitude to the choice of the educational task; creation of low-quality creative product; weakly expressed ability to analyze the result of one's activity; episodic manifestations of flexibility in assessing the results of joint activity; weakly expressed ability to predict the result of choice; reluctance to take responsibility for decision-making and lack of need to transform the situation (Sahlberg, 2009; Sysoeva, 2015; Simonton, 2017). The listed factors complicate the possibility of developing creativity in educational activities. This circumstance allowed us to determine the conditions for the development of the creativity of future specialists through situations of choice in academic activities. Students with different basic training participated in the study: graduates of colleges and art schools. The results of the comparative analysis of the first diagnostic test showed that the difference in the levels of creativity of students with different basic training is insignificant, so we did not further differentiate students on this basis and evenly distributed them into 2 groups; experimental (EG) – 32 people and control (CG) – 35 people.

Discussion

The musical and pedagogical process, which is associated with the constant creative search of a teacher of musical disciplines, operates in various pedagogical situations. A special place in considering the creative nature of the activity of a future specialist is occupied by performing instrumental activity. The specifics of the development of creativity of students of the faculties of arts are directly related to the creative nature of the musical pedagogical activity: purposeful, constructive, exploratory (the content of musical education), communicative, organizational (a process of musical education), and performing (Aksinina, 2011).

The structure of students' creativity is made up of personal qualities. Artistic activity is inextricably linked with creative activity, which is clearly manifested in the performing training of students. The creativity of the personality of a teacher of musical disciplines is a condition for original pedagogical activity since it transfers it from the skill of a teacher to the field of art.

The search and use of effective techniques and methods of problem-based learning in the process of studying musical instrumental disciplines will contribute to the activation of creative potential, the development of creative personal qualities, which will ultimately affect the quality of future professional activity. One of the main achievements of this activity will be a qualitatively unique result, distinguished by novelty and originality.

The essence of the concept of "choice situation in educational activity as a means of developing students' creativity" is analyzed, which is associated with the characteristics of the content of the choice situation, its potential, which ensures the development of creativity of future teachers of musical disciplines. The classifier of the situation is presented, its types. Types, forms and means are determined. The choice situation is a multivariate and multifunctional problem situation, the solution of which requires students to have a developed ability to make an independent decision, a desire and readiness to make a choice in a non-standard situation, the manifestation of strong-willed qualities in the process of solving the situation, possession of illogical heuristic procedures – intuition, insight, the ability to go to another plane to solve the problem.

A model, criteria and indicators of the process of developing creativity of future teachers of music disciplines based on the use of the choice situation in educational activities have been developed. The model includes a description of the functions and conditions for developing the creativity of future music teachers based on the use of the choice situation in educational activities: a classifier of the choice situation in educational activities – types, forms and means of its implementation; its phased use in the process of developing creativity; levels, criteria and indicators of the development of students' creativity.

The following criteria have been identified: motivational-targeted, cognitive, activity, and reflective. Among the indicators of creativity development are the manifestation of interest in choosing an educational task (interest), the need to independently choose the goal of academic activity (purposefulness), the desire to make a choice in a non-standard situation (risk-taking); the ability to choose the necessary information (vision of the problem), the ability to navigate in styles and genres, to promptly respond to changes in the interpretation of musical material (perception of new ideas and knowledge), the ability to produce a variety of associations (development of imagination); readiness to choose an educational task (readiness to choose), independence in implementing the selected task (independence), creating an original creative product taking into account the free choice of means (availability of an innovative product); the ability to independently analyze the result of one's activity (availability of one's own opinion), the manifestation of variability in assessing the results of joint activity (flexibility), the ability to predict the consequences of choice, transform the situation (responsibility for one's choice).

The pedagogical conditions for the development of creativity of future teachers of music disciplines through situations of choice in educational activities have been substantiated and experimentally verified: 1) stimulation of a meaningful choice by the student of an active personal position in educational activities, actualization of the internal need to independently solve the assigned educational tasks and the desire for personal development in professional situations (actualized motivation affects the probability of a positive result); 2) creation of a creative environment in the educational environment of an educational institution allows the future teacher of music disciplines to act creatively, to apply the acquired knowledge in a non-standard way in the educational process; 3) implementation of a differentiated and individual approach to learning provides stimulation of the development of creativity of future specialists through situations of choice, which is built on the basis of differences in general and special abilities, interests, and psychophysiological characteristics; 4) use of the program-methodical complex for the development of creativity of future teachers of musical disciplines (course program for choice, diagnostic materials, classifier of choice situations, recommendations to the teacher and student, means of checking and assessing the level of creativity development). The listed conditions form the basis for implementing the process of developing the creativity of future teachers of musical disciplines through choice situations in educational activities.

The formative stage of experimental and research work was aimed at increasing the initial level of creativity of the future teacher of musical disciplines. Achieving the set goal was determined by solving the following tasks: testing and experimental verification of the pedagogical conditions for the process of developing students' creativity based on the use of a choice situation in educational and musical activities; implementing a program of psychological and pedagogical training for the development of creativity; carrying out analysis, systematization, generalization and testing of the results obtained. The implementation of the set tasks in the educational process took place in three stages: initial, main, and final. At each stage, local tasks were solved to develop students' creativity, which was reflected in the steps – situations of choice. The tasks of the initial stage include preparing students for action in the conditions of a situation of choosing an educational task and developing creative qualities: interest, the ability to see and identify problems, imagination and fantasy, a positive attitude towards creative activity, the desire to make an independent choice. Steps-situations of choosing an educational task: information, musical material,

form of its presentation, partner, style of communication with the audience, performing means, interpretation. The teacher's actions at this stage are pedagogical support for the student. The task of the main stage was to actualize students' independent actions in a situation of choice with the development of such creative qualities as purposefulness, perception of new ideas, independence, having one's own opinion (argumentation of choice), readiness to choose. Steps-situations of choice: educational task, volume of work, level of complexity, forms of execution, partner, way of presenting results. The choice of material, presentation forms, communication style, performance means and interpretation remain among the previous tasks, but their implementation requires students to make some independent decisions. At the main stage, the teacher acts as a consultant, students begin to express themselves in a choice situation independently. The final stage's tasks are students' independent actions in a choice situation. Creative qualities such as initiative, focus on the result of educational and musical activity - the creation of a personal creative product, the presence of one's own opinion, the absence of categorical judgments, readiness and ability to choose, responsibility for making a decision are developed. Steps-situations of choice: partner (partners), goals of the activity, topic, a form of performance, the content of the activity, methods, the volume of work and method of presenting results, level of complexity, nature of the activity and its types, duration of the performance, a form of presentation of material, communication style, performance means, interpretation, value choice are developed. At the final stage, the teacher plays the role of an observer, students are given complete freedom of action in a situation of choice and revealing their manifestations of responsibility for making a decision.

The peculiarity of the formative methodology is the use of a choice situation to develop students' creativity in educational and musical activities. The choice situation is the central link on the basis of which the process of forming creativity is built. The methods and techniques for implementing the conditions for the formation of creativity are: didactic games, theater technologies, role modeling, compiling repertoire lists, psychological and pedagogical trainings on developing creative qualities, musical works, etc. The forms of implementing the process of developing students' creativity based on the use of a choice situation in educational and musical activities are individual, pair, and group classes. The individual form of solving tasks by students to choose from without the participation of other subjects – classmates, etc. In the pair form, there is a compromise choice of participants in the situation; at the same time, everyone who participates in the pair creative process contributes, and the chosen solution is defended together. The group form is characterized by a collective solution to the problem, discussion of different options for the task, development of the ability to negotiate, and the ability to communicate.

During the formative stage, the pedagogical conditions were checked. The implementation of the first condition is aimed at actualizing the motivation of students to make independent and free choices in educational and musical activities. Motivation is a set of stable motives, incentives that determine the content, direction and nature of the individual's activity, their behavior, which contributes to the disclosure of creative potential. The list of identified motives includes: interest in the problem, obtaining knowledge, the desire to independently choose a creative task, satisfaction from creative activity, the significance of one's own personality, competitiveness, interest in creating a personal original creative product (Gorban, 2018). The algorithm consists of four steps, where the first step is the choice of the type of musical activity. The second step involves the choice of educational tasks of different levels – reproductive, productive, and creative. The third step is to choose among tasks of varying complexity – those that are liked. The fourth step is the student's independent choice of a task from the three proposed (Gorban, 2018).

The creative task aimed at concentrating the motivation for choice was the compilation of individual repertoire lists by students. Students of the experimental group were asked to compile a list of 10-15 works that they would like to master, indicating the motives for their choice (musical and figurative content, originality of musical language, the opportunity to expand the musical worldview; the desire to get acquainted with this music, etc.). The identification of the hidden position of the experimental group students (the use of projection techniques) made it possible to obtain information about the motives for choice and the level of readiness of the student to choose an educational task.

Choice situations were simulated by the teacher and offered to students in the form of a didactic game, because it is in the game that the possibility of free choice is of paramount importance. The feeling of free choice constitutes its psychological basis, based on the positions of the students themselves, on their experience of the feeling of free choice in this process (Qianyi et al., 2021, p. 53). Choice situations must meet several requirements, namely: to be in the zone of proximal development of a young person and affect the sphere of his current needs and interests; to be included in the system of students' life activities. The

basis for expanding freedom of choice should be the activity's success, which requires a well-thought-out mechanism for protecting the student from his mistakes.

The list of educational tasks of the project "Music in Our Life" includes the search for musical material (musical work); theoretical information (about the composer, style and genre of the work); choosing the form of written presentation of a musical work (written annotation), choosing the form of oral presentation of music (oral annotation), choosing a partner in the ensemble, emotional and expressive means, interpretation, etc. During the experimental work, it was found that students are not ready for independent choice, there is an irresponsible choice that is random in nature. Thus, out of 18 students, only 22% (4 people) consciously made their choice. Among them, Nikita P., who presented an interpretation of B. Filts. "Sad song" (Shestopalova, 2019) stood out in particular. Usually, in a situation of free choice of a musical work at the first stage, situations with limited freedom of choice were mainly used: with a small list of musical works. However, during the independent work of students, a conscious and responsible choice begins to manifest itself in the search for new, interesting musical material. Thus, student Oksana S., choosing the plays by V. Kosenko "Rain" and "Polka" (Shestopalova, 2019), pointed out the simplicity of the musical language of the work, the brightness and accessibility of musical images, which made her oral presentation interesting.

The next task – choosing a method of presenting music – also included options for a written annotation (reference and informative – "classical", "artistic" – essay, essay, poetic form) and oral (mini-lecture, story, riddle, staging of a musical fairy tale, etc.). Three options for writing a "classical" oral annotation included different levels of tasks. The first option involved listing a number of patterns, facts, phenomena, and features of choosing a given work. The second option was based on the principle of comparison, which includes determining the similarities and differences in the features of the work. The third option is search, which contains an analysis of the style of a musical work and a performance solution, which are associated with the search for material from musicological and fictio literature. The students' choice of the oral, more complex version of the annotation is associated with a developed ability to creative activity. Students of the experimental group in the oral annotation preferred a fairy tale and a riddle, which is due to the appeal to music used in pedagogical practice classes with schoolchildren.

A specific feature of the creative nature of the educational and musical activity was performing an activity, which was modeled in the "Music in our life" project. Students learned to set the goal of their activity independently, mastered search, research activities, constructed, organized and implemented the form of presentation and transmission of material using interpretation. This became possible due to the free choice from various alternatives, which stimulates the development of independence, susceptibility to new ideas, and a creative attitude to educational and musical activity. An attempt has been made to systematize creative tasks to develop students' personal creative qualities based on a choice situation. Steps – situations of choice that arise in the process of educational and musical activity have a different nature, imply a sequential solution of tasks. These are the search and selection of new musical material, new forms of its presentation, the choice of the form of written and oral annotation, the choice of performing means, interpretation, the choice of partners from the ensemble, the value choice. Tasks for the development of creativity based on the use of the choice situation are distributed over stages, at each of which the corresponding tasks are set, in turn, each task contains step-situations.

The choice situation in the educational and musical activity of the future specialist is presented in terms of its nature: in the purposeful – the choice of the goal; in the constructive – the choice of the form of presentation of musical material; in the research – the search and selection of new musical material, repertoire, information about the authors, written annotation; in the communicative – the choice of the style of communication, oral annotation; in organizational – the ability to make the right choice in non-standard situations; in musical and performing – the choice of performing means, the choice of interpretation, the choice of ensemble partners.

The idea of a "creative room" was used to create a creative environment in a higher education institution, saturated with situations of choice. The project "Music in Our Life" acted as a kind of "creative room", a creative environment created in the educational space, where students can choose for themselves what is closer and more interesting to them. Since the creative environment is the personal space of each student, which flexibly responds to his requests, aspirations, needs, we are talking about the functioning of a set of situations of choice precisely in the creative environment. In this context, we considered the project "Music in Our Life" as a pedagogical workshop, where everyone is given the opportunity to show their creative

individuality, which allowed us to imagine the implementation of a differentiated and individual approach to learning as the third pedagogical condition, which provided targeted and gradual stimulation of the development of creativity of future teachers of music disciplines through situations of choice in educational reflection. The condition involves the student's transition from a no-alternative position to independent actions in a situation of choice and is one of the stimulating factors that influence the development of creative qualities and is reflected in the student's creation of a personal creative product.

A significant factor that ensures the development of the student's creativity is educational reflection, which in scientific research is understood as the individual's awareness of the limits of his knowledge and ignorance, goals, methods, results of activity, possible and current difficulties, their causes and ways to overcome them. Educational reflection participates in self-regulation mechanisms that allow students to be subjects of activity (Epstein, 2003; Karpenko, 2016). Reflective processes include: highlighting the conditions of subject activity that contradict existing knowledge and skills; fixing the boundary of knowledge and ignorance, translating ignorance into the form of an educational task; modeling the method of action, using existing ones in the arsenal and attracting new means in the course of action; establishing the correspondence of the result to the goal of activity; highlighting real and possible difficulties in the process of activity, analyzing their causes and ways to overcome them (Ivanchenko, 2017).

To ensure the process of developing students' creativity, the following methods of educational reflection were included: stopping, remembering the course of activity where difficulties arose; isolating units, methods of activity, creating a structure of activity, identifying internal contradictions and ways to achieve the best results; analyzing the results of activity, comparing the results obtained with the goals set; clarifying the personal meaning of activity, one's own educational gains; looking at one's own educational activity and its results from the outside (presenting oneself as another, external subject); comparing the obtained "real self" with the "ideal self"; correcting educational goals and the course of further activity (Rebriy, 2012). Addressing similar musical phenomena and facts creates conditions for their active comprehension and synthesis, which contributes to developing creative competence as one of the creative personal qualities. This applies to both understanding the genres of classical and contemporary music and mastering the stylistics of different musical directions. For example, observing the reaction of students in the experimental group made it possible to reveal their genuine interest in the following proposed topics: "Journey to the Country of Baroque", "Movie Music", "Jazz Plus... ", "Invitation to Dance: Variety of Genres". The study of joint creative products of activity on these topics made it possible to draw a conclusion about the possibilities of ensemble music making, which gives students a deeper understanding of music.

In the process of preparing and conducting the project "Music in Our Life", the creative abilities of students were actualized, which was expressed in the creation of new, original forms of presentation of musical and textual material, storylines in musical stagings, in work on musical images – characteristics, improvisation. For example, students of the experimental group were offered the topic "Jazz plus..." within the framework of which they independently chose a work. The degree of independence – 3 options - students left.

In order to determine the motives of students' choices, we added a questionnaire to traditional tasks. Analysis of the responses to the questionnaire "All this jazz" allowed us to identify the predominance of cognitive motives in students, which was expressed in interest in the topic of the project, and indicated the activation of cognitive components of creativity: interest in the problem, new ideas, reduction in the manifestation of inertial thinking.

There was a manifestation of interest in new, unusual forms of presentation of musical material. This was reflected in the oral annotation, for example: in the form of a riddle, mini-quiz, fairy tale, skit. The number of students who chose the first version of the annotation significantly decreased, which is associated, in our opinion, with the actualization of interest in the project topic and the possibilities of independent search.

Management of any process, in particular the development of creativity, is only possible with taking into account the changes occurring within the process itself (Molyako, 2013). Taking into account intermediate changes in the creative qualities of the personality of future specialists during the formative stage of the experiment involved constant monitoring of these changes, as well as the selection of methods and methods for correcting the process by diagnosing the development of the studied student's personality trait. The diagnostic methodology in our study was based on pedagogical observation, questionnaires (four author's

questionnaires), testing (J. Kincher, N. Vishnyakova) (Pavlenko, 2016), the method of expert assessment, the method of competent assessment.

The means of checking and assessing the level of creativity development of future teachers of music disciplines through situations of choice in educational activities include analysis, comparison, systematization, generalization, questionnaires, the method of competent assessments, the method of collective expert assessment, and methods of mathematical statistics. The Mann-Whitney U criterion was used to prove the significance of the differences in the indicators of the level of creativity in the EG and CG after conducting the formative methodology (Zhluktenko et al., 2001). We put forward the following hypothesis: H0 – the level of creativity in the CG exceeds the level of creativity in the EG. Hj – the level of creativity in the CG does not exceed the level of creativity in the EG. The results of the mathematical and statistical verification of the reliability of the differences between the classes of respondents are presented by Yuliia Savchenko in Table 3.

Table 3.
Statistical test of the reliability of differences in creativity parameters between EG and CG after the formative stage of the experiment.

№	Creativity parameters	Average rank (EG)	Average rank (CG)	Mann-Whitney U test of agreement in estimates
1.	Interest	37,58	30,73	445,500
2.	Purposefulness	37,91	30,43	435,500
3.	Risk appetite	38,75	29,66	408,000
4.	Vision of the problem	40,34	28,20	357,000
5.	Receptiveness to new ideas and knowledge	37,77	30,56	439,500
6.	Development of imagination	36,78	31,46	471,000
7.	Willingness to choose	37,19	31,09	458,000
8.	Independence	37,69	30,63	442,500
9.	Availability of a creative product	37,38	30,91	452,000
10.	Having your own opinion	38,47	29,91	417,000
11.	Flexibility	36,81	31,43	470,000
12.	Responsibility for the choice made	38,75	29,66	408,000
	General index	38,39	29,99	419,000

Note. Significant differences are found between the EG and the CG in the parameter "vision of the problem" (U3Mn = 357 **), "propensity to risk" (U3Mn = 408 *), "presence of one's own opinion" (U3Mn = 417 *), "responsibility for one's own choice" (U3Mn = 408 *), as well as in the parameter "general index" (U3Mn = 419.5 *). After the experimental exposure in the EG, these indicators increased significantly. Interpreting the results of the statistical test, we can assume the following: as a result of the experimental work, the most significant differences are observed in the EG respondents in the parameter "presence of one's own opinion", which in our study corresponds to the indicator "ability to analyze the result of one's activities independently". This is due to the actualization of the respondents' reflective skills as a result of the implementation of a differentiated and individual approach to learning, during which purposeful and gradual stimulation of the development of creativity of adolescent students through situations of choice in educational reflection is provided. Next are the parameters "propensity to risk" and "responsibility for one's choice", which indicate the reasonableness of the risks of future specialists in uncertain situations and the adequacy of their ability to predict the consequences of choice, and is associated with the actualization of the motivational-goal and reflective sphere of schoolchildren in the process of research and experimental work. The parameter "vision of the problem" indicates the developed ability of the student to select the necessary information during educational activities, and is a particularly significant personal quality for a teacher of musical disciplines in the modern world. It is possible to establish a certain connection in the significant differences between these indicators of the development of creativity and the situation of choice, because the ability to independently analyze the result of one's activity, the desire to make a choice in a non-standard situation, the ability to predict the consequences of choice, transform the situation, the ability to select the necessary information indicate not a set of disparate personal qualities, but a manifestation of systematicity in the development of a complex of creative qualities precisely in the process of the experiment.

According to the study results, positive dynamics are observed not only in the EG, but also in the CG. This is due to several factors: the influence of the creative environment formed in the educational space of the educational institution; the specifics of the creative nature of educational and musical activity; a differentiated and individual approach to students. Comparing the results of the control diagnostics in the EG with the results of the CG, in which the experimental work was carried out fragmentarily, we found significant differences in the severity of changes, which is a confirmation of the feasibility of the model we proposed and the effectiveness of the conditions of the educational and methodological complex developed on its basis for the development of creativity of future teachers of musical disciplines through situations of choice in educational and musical activities. The information presented in Table 4 shows that the number of students with a level of creativity "low" and "below average" decreased, due to this there was a significant increase in the "average level" in both groups.

Table 4.
Dynamics of the development of students' creativity based on the use of a situation of choice in educational and musical activities.

	Beginning				**End**			
Groups	EG		CG		EG		CG	
Levels	Per.	%	Per.	%	Per.	%	Per.	%
	32	100	35	100	32	100	35	100
Low	6	18,6	6	17,4	-	0	2	5,6
Below average	12	37,2	11	31,9	5	15,5	6	17,4
Average	11	34,1	14	40,6	12	37,2	8	52,2
Above average	2	6,2	2	5,6	11	34,1	7	21,7
High	1	3,1	2	5,6	4	12,4	2	5,6

As a result of modeling the process of developing the creativity of future teachers of musical disciplines based on the use of the choice situation in educational activities, the conditions were determined and methods of its implementation were identified, and the programmatic and methodological support of the studied process was developed. The process model received a specific embodiment in the step-by-step system of using the choice situation in educational activities developed by us, which includes: a lecture course on the choice of "Modern trends in the development of musical education", a psychological and pedagogical workshop on the development of creativity, compiling repertoire lists, creation, ensemble music making, a competition of a self-studied work "Music for children", a student group "Music for children" within the framework of students' research work, individual lessons in instrumental training disciplines, organization of extracurricular activities of students – festivals, creative competitions, role-playing games, theatrical events.

Conclusions

The conducted research and experimental work proved the validity of the development of creativity of future teachers of musical disciplines through the situation of choice in educational activities and confirmed the effectiveness of the developed pedagogical conditions, which was manifested in the dynamics of students' creativity levels by the end of the experimental work. The issues of creativity of future specialists and the specifics of its development in educational activities were clarified using the example of students studying at the faculties of arts. It was proved that the problem of creativity of a future teacher of musical disciplines is a manifestation of the creative nature of his work, due to the specifics of pedagogical activity, which is public in nature, is carried out in front of a certain audience and requires the ability to manage one's feelings and moods. Thus, the author's methodology for the formation of creativity of future teachers of musical disciplines was substantiated and experimentally tested. The criteria and levels of formation of this phenomenon in students in the process of musical educational activities are presented. The results of the formative experiment are analyzed and their reliability is proven.

We see the prospect of further scientific exploration in developing the structural and functional components of models for creativity formation in various types of musical activities, as well as in shaping individual strategies for independent creative activity among future teachers of musical disciplines.

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The implementation of a corpus-construction project on student translators: competence development and challenges

一项学生译者参与的语料库项目：能力发展与挑战

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Abstract

This study investigates a corpus-construction project implemented at a foreign language university over two years, aiming to explore its impacts on student translators and the challenges encountered by teachers in project management. Results show that students have developed multidimensional competence, including enhanced translation skills and technological competence, development of cognitive skills and critical thinking disposition, improvement of collaboration skills and teamwork, as well as historical responsibility and ethical awareness. However, teachers encountered challenges such as corpus difficulty and ambiguity, technological barriers in corpus construction, and difficulties in team management. This research not only enriches the theory of translation education, but also provides practical implications for curriculum design and teaching practices, as well as the implementation of large-scale authentic projects across different domains.

Keywords: Project-based learning, translation education, corpus, project management, competence development.

摘要：

本文阐述了在某外国语学院开展的为期两年的语料库建库项目研究，旨在探究其对学生译者的影响以及教师在项目管理中面临的挑战。结果表明学生在多方面受益，包括翻译技能与技术能力提升、认知技能和思辨特质发展、协作技能与团队合作增强，以及历史责任感和伦理意识的培养。然而，教师也面临了语料复杂和文本模糊、技术障碍以及团队管理困难等挑战。本研究不仅丰富了翻译教育理论，还为课程设计和教学实践提供了建议，并对不同领域开展大规模真实项目提供经验。

关键词：项目式学习，翻译教育，语料库，项目管理，能力发展.

Introduction

With information technology posing both opportunities and challenges to the translation industry, institutions are seeking for innovative ways to cultivate student translators with comprehensive abilities. In translation education, traditional didactic approaches often fall short in equipping students with the multifaceted skills required in real-world translation scenarios, where technical proficiency, cognitive skills and collaborative competence are paramount. In such context, project-based learning (PjBL) has emerged as a pedagogical strategy to cultivate translators' essential competencies through authentic tasks (Putra et al., 2022; Ribeiro et al., 2023).

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In the realm of translation education, corpus-based projects could enhance learners' translation quality, productivity and familiarity with computer-aided translation (CAT) technologies (Alhassan et al., 2021). Corpus construction projects create opportunities for translator trainees to acquire language patterns, collocations, specialized terminology and translation strategies, thus bridging the gap between theoretical learning and practical translation tasks. However, existing studies predominantly focus on small-scale, classroom-bound corpus activities (Mohammed, 2022), leaving a lacuna in understanding the dynamics of institutionally coordinated, large-scale projects. Meanwhile, PjBL highlights collaborative, experiential learning rooted in social constructivist theories (Vygotsky, 1978), yet its application in specialized translation domains remains under-researched. For example, PjBL integrated into the legal translation domain, presents unique challenges including terminological complexity and ethical sensitivity. This study addresses this gap by implementing a corpus-construction project involving military trial texts at a foreign language university, over an extended period of two years. Situated at the intersection of translator education, corpus linguistics, and project-based pedagogy, the research aims to investigate how such a large-scale authentic project influence students' competence development. Additionally, it probes instructors' challenges in balancing pedagogical goals with project implementation in authentic situations. Such insights are critical for optimizing translator-training models in specialized domains and broader contexts.

Research questions:

RQ 1: How did participation in the corpus-construction project influence the competence development among student translators?
RQ 2: What challenges did instructors encounter in managing such a project?

The structure of the article presents as follows. The literature review section examines existing research on corpus-based pedagogy and PjBL in translation education. The methodology section details our qualitative research design, including data collection and analysis approaches. Next, the results and discussion section present key findings of the study, discussing the impact of PjBL on student outcomes, as well as challenges encountered in implementing the PjBL from the perspectives of instructors. Finally, the conclusion summarizes the main findings, addresses the limitation of the current study and proposes directions for future research.

Literature Review

Corpus-Based Translation Pedagogy

Since the 1990s, the application of monolingual corpora, parallel corpora, and other corpus-based resources has transformed translation research and pedagogy (Li & Pan, 2023). Featured by the data-driven learning mode, the corpus-based pedagogy enhances learners' ability to identify collocations, resolve syntactic ambiguities, and improve terminological precision, which applies widely in translation classrooms. Xiao and Hu (2015) underscored the value of parallel corpora in addressing structural divergences between English and Chinese, which could foster learners' metalinguistic awareness. Mohammed (2022)'s study found that student translators not only used online corpora but also created their own corpora when engaging in the translation projects, which improved their translation efficiency and quality. Zhao and Mu (2020) reported that the corpus-based translation teaching enhanced learners' research thinking and practical translation skills. These findings align with the social constructivist principles (Vygotsky, 1978), where collaborative engagement with authentic tasks promotes cognitive scaffolding and procedural knowledge acquisition. In such case, the integration of corpus tools into PjBL frameworks within translation education receives popularity, in which corpora provide empirical linguistic data to guide translation decisions, while PjBL structures the application of this data in authentic, goal-oriented tasks.

Project-Based Learning and its Application in translation education

PjBL can trace back to the earlier 20st century, when scholars like John Dewey emphasized the importance of experiential learning in guiding learners' engagement and higher-order thinking. According to Krajcik and Shin (2014), there are six crucial elements of PjBL, namely, a driving question, the focus on learning goals, participation in learning practices, engagement in collaborative learning, scaffolded learning technologies, and the creation of tangible artifacts. With these features, PjBL has the prospects of exposing learners to both self-directed learning and collaborative problem-solving processes. From the lens of social

constructivism theory, PjBL engages learners in real-world projects, where meaningful learning occurs through social interaction and scaffolded guidance. Researchers have endorsed the efficacy of PjBL on students' learning such as *affective* outcomes (e.g. perceptions of the benefits of PjBL), *cognitive* outcomes (e.g. knowledge acquisition and higher-order thinking) and *behavioral* outcomes (e.g. skills and engagement) (Guo et al., 2020). Over the years, PjBL has been applied widely across different disciplines, such as engineering, business and economics, STEM, and language education (Dias-Oliveira et al., 2024; Greenier, 2020; Lavado-Anguera et al., 2024; Seo et al., 2024).

With the transformation of translation industry, the translation is no longer an individual work but requires translators to work collaboratively in large-scale projects. PjBL, through engaging translators in the authentic or simulated projects to create the real work environment, receives popularity in translation education. Li, Zhang and He (2015) conducted a project incorporated into business translation; reporting students not only enhanced their translation-specific competencies but other skills including teamwork and collaboration, critical thinking, presentation skills. Another study conducted in an Islamic university echoed that exposing learners to PjBL enhanced their translation performances and soft skills including problem-solving, communication and creativity (Putra et al., 2022). With the advent of digital technology, translation projects can now incorporate elements such as corpus-based translation technology, CAT tools, and online collaboration platforms. For instance, engaging student translators in an online crowdsourcing translation project reported students' significant gains in subtitling knowledge and skills (Tzou, 2024). The online PjBL approach integrated into the technical translation courses was found to enhance learners' self-regulation, and self-confidence in autonomous learning (Ribeiro et al., 2023). These technological advancements have further expanded the scope of PjBL in translation education.

Despite of the benefits of corpus-based pedagogy and PjBL in translation education, critical limitations persist as follows. First, research on corpus-aided translation training has predominantly focused on short-term interventions or isolated skill acquisition, with limited attention to how extended, collaborative projects influence translator trainees' holistic development. Second, existing studies have examined learners' perceptions on PjBL in translation classrooms (Mohammed, 2022; Ribeiro et al., 2023), however, teachers' authentic experiences in the implementation of PjBL are scarcely documented. These gaps collectively underscore the necessity of the present study, which not only advances theoretical discourse on technology-mediated translation education, but also provides practical references for designing future sustainable projects across different domains.

Methodology

Research Design

Due to the exploratory nature of the study, we adopted a qualitative research design to investigate the benefits and challenges from the perspectives of student translators and teachers. The study employed multiple data sources—including students' reflective journals, semi-structured interviews on both students and teachers—to triangulate findings and ensure the methodological rigor (Creswell & Poth, 2023) .

Participants and sampling

As participants were required to engage in translation and corpus construction tasks, we adopted purposeful sampling to recruit participants mainly from the *Translation and Interpreting Department*. Due to the long-term nature of the project, we recruited participants on a voluntary basis, involving 97 student translators (78% female, 22% male), 15 EFL instructors, together with three project supervisors and two technical experts to oversee quality control. Student participants were randomly assigned into 15 groups (5-8 students each), with one guiding instructor in each group. Ethical approval was secured prior to data collection, and informed consent was obtained from all participants, with assurances of anonymity and confidentiality.

Research procedure

Unlike most studies conducting PjBL activities integrated into a specific course, our study implemented this longitudinal large-scale project due to practical needs. In 2021, the target university received governmental funding support on the translation work of the *Transcripts of the proceedings of XXX Military Tribunals* (volume 11-40). Subsequently, the university decided to launch a corpus construction project, aiming to complete six different corpus covering 8300000 words (volume 11-25). The project aimed to

engage student translators in real-world translation work, help teachers acquire the authentic legal corpus for research work and improve teaching effectiveness, and promote historical responsibility. Prior to the implementation of the project, all participants attended a training session that covered:

a) The historical and legal significance of military tribunal transcripts.
b) The project objectives and expected outcomes.
c) Ethical considerations in handling sensitive legal documents.
d) Copyright and data security protocols.

To start the project, students were required to conduct the initial text proofreading for English PDF-to-WORD conversion. This work was very significant as the source texts were digitally scanned, which contained misspellings, omissions and ambiguous words. To strengthen the accuracy of the subsequent parallel corpus construction work, all participants constantly engaged in generating clean files with both original and target texts. Given to the complexity of the project, the procedure consisted of several phases starting from corpus preparation to finalized corpus (see Table 1).

Table 1.
The schedules and key activities of the project

Timeline	Key Activities & Deliverables
Phase 1 Text proofreading	Conduct initial text proofreading for English PDF-to-WORD conversion Identify misspellings, omissions, and ambiguous texts Complete evidence/witness lists and documented revisions in errata sheets Complete the proofreading and generate clean files in plain texts
Phase 2 Corpus development	Parallel text alignment using CAT tools Terminology extraction and glossary development Quality assurance through triple-checking system
Phase 3 Corpus enhancement	Text annotation for linguistic features (e.g., legal terminology, named entities) Metadata tagging for document properties Conduct inspection and quality assurance
Phase 4 Quality verification and corpus standardization	**Delivered artifacts:(six corpus covering 8300000 words)** ✓ Bilingual sentence-aligned parallel corpus (plain text) ✓ Bilingual sentence-aligned parallel corpus (with word segmentation) ✓ English and Chinese monolingual plain-text corpora ✓ English and Chinese monolingual plain-text corpora (with word segmentation) ✓ Bilingual TMX files Bilingual Trados translation memory

To provide the technical support for this large-scale project, the project organized more than 10 training workshops (online and offline) at regular intervals, covering initial text cleaning and formatting standardization, corpus alignment techniques, terminology management and quality assurance protocols. The project assigned one instructor to each group, mentoring them to complete assigned tasks and conduct quality assurance. During the process, student groups worked collaboratively to negotiate tasks, resolve problems such as language misunderstanding or technical barriers, and consult their supervisor in case of any confusion.

Materials and instruments

This study utilized the qualitative methods to collect data from three instruments to capture multidimensional perspectives. The raw data consisted of students' reflective journals and semi-structured interviews on both teachers and students.

Students' Reflective Journals

Students' reflective journals were collected at strategic intervals throughout the two-year project, and 62 students delivered the journals in the written form on voluntary basis, yielding 43896 words in total.

Student Interviews

The present study also conducted the semi-structured interview on five groups of 30 students via purposive sampling to represent diverse roles and proficiency levels. The interviews were audio-recorded and

transcribed verbatim, and the interviewees were informed of the anonymity and confidentiality. Sample questions were as follows:

- Why do you choose to participate in such a large-scale translation project?
- Have you developed any skill from participating in this project?
- Have you gained any insight in shaping your professional aspirations?
- Have you encountered any challenges during the process? If yes, how did you resolve such problems?

Teacher Interviews

To triangulate the data analysis, the present study also conducted a post-project interview on five teacher participants, including one project supervisor and one technical expert. The interview questions on teachers were mainly to collect their responses to:

- The pedagogical design of the corpus project;
- Their perceived alignment between project outcomes and curriculum goals;
- Challenges encountered in mentoring student translators during the project;
- Recommendations for implementing future scaling corpus-based projects.

Data Analysis

This study employed a qualitative methodology to examine the impacts of the large-scale project on student translators' learning outcomes. Following Braun and Clarke's (2006) thematic analysis framework, we systematically analyzed qualitative data from the above three data sources. Two researchers independently read and interpreted the data to generate categories and themes. To ensure methodological rigor, we implemented multiple validation strategies, including data triangulation across sources and consultation with external qualitative research experts in case of any disagreements. Due to the exploratory nature of the present study, our comprehensive analytical approach was suitable to develop nuanced understandings of both the transformative potential and implementation challenges of longitudinal, corpus-based translation projects in EFL contexts.

Results

RQ 1: How did participation in the corpus-construction project influence the competence development among student translators?

Through our thematic analysis, four core themes emerged from the qualitative data (see Table 2), which were presented below with supporting evidence from coded excerpts.

Table 2.
Students' perceived competence development

Competence development	Descriptions and examples
Translation skills and technological competence	▸ Mastery of legal English conventions, interdisciplinary knowledge and terminological precision ▸ Application of "faithfulness, expressiveness, elegance" translation principles and flexibility in selecting translation strategies ▸ Enhanced information literacy (grammar checks, tool utilization such as CAT)
Cognitive skills and critical thinking dispositions	▸ Analytical rigor, reasoning skills (seeking for linguistic equivalence and identifying translation errors) ▸ Open-mindedness and cognitive maturity
Collaboration skills and teamwork	▸ Peer support in encountering problems ▸ Effective knowledge sharing and collaboration (e.g., online collaborative platforms for real-time resolution) ▸ Negotiation in solving disagreements
Historical responsibility and ethical awareness	▸ Moral values as professional practitioners ▸ Ethical awareness in adhering to historical facts ▸ Unbiased decision-making in translating authentic events

Translation skills and technological competence

During the corpus cleaning and proofreading work, students had to compare and analyze whether the target texts aligned with the source texts, and they did a lot of revision work. The majority of students reported significant improvements in the translation skills and mastery of specialized terminology. Some excerpts were as follows:

There were many legal terminologies, long and complex sentences in the original texts. Translation strategies such as omission/addition and passive voice conversion were effective, which are critical for legal text fidelity and offer recommendations for my future translation work. (S23- student journal).

Through comparative analysis of Chinese and English texts, I improved my translation skills by initially identifying problematic areas in translations, consulting instructors with questions, and making revisions based on experts' feedback. (S7-interview-ref).

After phase one was completed (proofreading and text cleaning), students were trained and prepared for the corpus construction work. During this process, they improved their digital literacy and technical proficiency, including the mastery of CAT tools (e.g., Trados, AntConc, MemoQ) and AI applications.

I never used the CAT tools in my translation practices before. This project opens up new insights for me to acquire translation technology, which improves the translation efficiency and facilitates the large-scale project management. After completing the project, I tried to create my own bilingual corpus in political texts translation, which aid my future translation work. (S25- student journal).

I am glad that those students have not only improved their translation skills but also enhanced the digital literacy. The project engages learners in authentic tasks, requiring them to create specialized terminology, produce TMX files with certain tools, as well as master the CAT software. (T4-interview-ref)

Cognitive skills and critical thinking dispositions

When exposing to authentic translation tasks, student participants also developed their cognitive skills, including analytical rigor, independent reasoning and decision-making skills, as S6 stated in the interview: When addressing challenges like mistranslation, or conceptual gaps, we need to exercise preliminary judgment and strategic decision-making, which strengthened our logical reasoning capabilities and analytical precision in maintaining linguistic equivalence.

We learnt to identify and analyze sentences that violated translation standards such as over-translation or mistranslation and then offered rational revision notes, which significantly enhanced my analytical and reasoning skills. Gaining an in-depth understanding of case details enabled me to approach ambiguous sentences with greater logical reasoning, ultimately enhancing my translation accuracy and explanatory precision. (S32- student journal).

Additionally, the student participants not only improved their cognitive skills, but their critical thinking dispositions as well. As indicated by Teacher 2, those students had developed cognitive maturity in translation practices, through searching for multidimensional resources, and were open-minded in absorbing different perspectives in the peer review process.

Collaboration skills and teamwork

As this is a long-term project implemented on student translators, they perceived the significance of teamwork in improving project efficiency. Knowledge sharing on effectively detecting errors in the proofreading phase is significant, which saves them a lot of time. Additionally, they perceived that it significant to offer help to their peers and promptly respond to others. Some excerpts were selected from students' reflective journals:

We often encounter difficulties in the first phase; for example, how to detect the mismatch of original texts and translation texts, identify the punctuation errors, confirm the legal terminology, etc. At this time, posing the questions in the online chatting boards and seeking for help is a good choice. (S12)

Translation is not individual work, which requires teamwork when engaging in large-scale projects. The instructor asked me to act as the leader in my group, so I need to coordinate with my team members effectively. (S41).

The instructors also reported the enhanced collaboration skills among students. A case in point was resolving discrepancies in translating "*command responsibility*", students collaboratively analyzed existing parallel corpora, consulted the specialized databases, and negotiated solutions, thereby transforming disagreements or conflicts into consensus-building opportunities.

Historical Responsibility and Ethical Awareness

Through dealing with authentic military tribunal documents, student participants demonstrated a heightened sense of historical responsibility throughout the project. In their reflective journals, many emphasized the importance of accurately representing historical events. For example, one stated:

I realized that every word we translate and every correction we make in the corpus is a step towards preserving the true history of the military tribunals. A single error could potentially distort the original historical events, so we must be extremely serious regarding this challenging yet meaningful task (S16-student journal).

Numerous students, indicating a collective understanding that their work was not only involving linguistic transfer, but also related to moral values as professional practitioners, echoed this sentiment. During the process, many students have developed the sense of historical responsibility in handling the authentic corpus.

When translating sensitive contents related to war crimes, Student 16 noted, "It was emotionally challenging to translate the testimonies of those criminals, but I knew I had to set aside my personal feelings and translate accurately". This reflects an ethical approach to translation, where students recognized the significance of providing an unbiased account of history. In cases where historical terms had controversial translations, student participants also engaged in ethical decision-making processes. One student said, "Language equivalence is not difficult, but we had to consider the historical and cultural implications. We referred to multiple academic sources and consulted with teachers to ensure our translation was both accurate and respectful of historical facts" (S29-interview-ref). This shows how students took responsibility for their translation choices, going beyond surface-level translation to engage with the complex ethical and historical dimensions of the task.

Moreover, teachers themselves felt a sense of historical responsibility in guiding the project. Teachers' awareness of their role in shaping students' ethical and historical understanding was a significant factor in promoting these values within the project. One instructor responded,

> As mentoring instructors, we have the responsibility of guiding students to understand the importance of adhering to historical accuracy. Enhancing students' translation skills is not the only purpose, it is equally crucial to develop the sense of moral ethics towards facts (T5-interview-ref).

RQ 2: What challenges did instructors encounter in managing such a project?

While the corpus project yielded significant educational benefits, teacher interviews revealed three major challenges encountered in the implementation of such a longitudinal project. These obstacles including *the corpus difficulty and text ambiguity, technological barriers, and difficulties in team management*.

Regarding corpus difficulty, teachers pointed out that the historical archives as primary resources presented a multitude of difficulties. A wide variety of specialized terms made it challenging for both teachers and students to understand the source material accurately, which might affect the quality of the translation without specialized training. Just Teacher 3 stated.

The legal and military jargon in these documents was highly specialized. There were terms that were unique to the military tribunals of that era, and their meanings were not always clear even after consulting multiple dictionaries.

Additionally, some teachers responded that the original military tribunal transcripts were in a poor state. There were missing pages, faded texts, and unclear printings, which made it extremely difficult to piece together the complete story. As teacher 5 said: "taking texts in Volume 23 as example, there were several keywords where the printings were unclear, we had to rely on guesswork and cross-referencing with other sources to fill in the gaps". Therefore, this lack of completeness not only hindered the translation process but also raised concerns about the accuracy of the final corpus. Both student and teacher participants had to do a lot of work in the proofreading work, which required a lot of time and devotion to the project.

Technological challenges emerged as another major barrier, particularly during the early phases of the project. As not all teachers or students were familiar with the CAT tools, while it took some time for all participants to master specialized software required in the corpus construction work. Tools like ABBYY FineReader struggled with ambiguous evidentiary notes, exhibiting a large error rate for identifying original texts, while Trados SDL was incompatible with some original documents. Teacher 2 recalled the difficulties in bringing students up to speed: "We had to train students from zero on XML tagging for metadata—some initially marked entire pages as 'unclear' when encountering a single illegible character."

Perhaps the most persistent challenges occurred at the team management, where coordinating over so many participants with varying skill levels required innovative solutions. The two-year duration of this large-scale project led to motivational fluctuations, with task completion rates dropping from 92% in the first six months to 72% in the final six months as student fatigue set in. Nearly 30% of late-stage journals mentioned "*burnout from repetitive quality checks*". This lack of motivation and consistency in performance affected the overall efficiency and continuity of the project. Additionally, students with verifying competence levels and personalities made the team management work more challenging.

Collectively, these challenges extended the project timeline beyond initial projections. However, as several teachers noted, the struggles themselves became valuable learning experiences, which could provide references for future PjBL implemented on students.

Discussion

The implementation of the two-year corpus construction project for student translators provides a multifaceted lens to examine the interplay between project-based learning, translation pedagogy, and interdisciplinary skill development. While PjBL has been widely investigated in translation education (Garcia Gonzalez & Veiga Diaz, 2015; Moghaddas & Khoshsaligheh, 2019), its application in large-scale corpus construction remains underexplored. Unlike traditional PjBL approaches focusing on the design of appropriate teaching activities, our study engaged learners in authentic translation corpus, and interaction with CAT tools, machine translation software and AI applications in completing authentic tasks. Such human-machine interaction not only enhanced students' technology literacy, but improved their metacognitive awareness of translation knowledge and strategies as well. These findings echo the cognitive theory of multimedia learning, which proposes that multimodalities create conditions for learners to process contents in an effective way (Mayer, 2005; Shadiev et al., 2024). By aligning bilingual texts and annotating terminology, learners internalized patterns of language equivalence and divergence, reinforcing the interplay between declarative knowledge (e.g., legal terminology and sentence patterns) and procedural skills (e.g., corpus alignment).

The findings also indicate the development of *social* and *cognitive* skills (e.g. team work, critical thinking) among student participants, which align with the social constructivist approach positing that knowledge is constructed through authentic and socially mediated tasks (Vygotsky, 1978). When working towards the assigned team tasks, individuals need to share knowledge or offer help to their peers, which could strengthen their collaboration skills and teamwork. Further, those student translators need discuss, negotiate and reconcile different perspectives when encountering idea collision and disagreements during the project; which stimulated their critical thinking development (Alwafi, 2023).

Moreover, as our project involves translating military tribunal texts with legal jargon, historical contexts, and ethical dilemmas, students also developed their *historical responsibility and ethical awareness*. Taking authentic historical corpus as situated ethical practice, this study extends Baker's (2006) concept of "*translator activism*" to educational settings. For example, students' discussions on translating culturally sensitive terms (e.g., "justice" in cross-legal systems) highlighted their growing awareness of linguistic hegemony and their social responsibility to preserve historical nuance—a finding that aligns with recent

calls for "incorporating social responsibility in translation projects" (Muftah, 2024). From this lens, our study extends the traditional boundaries of translation education, highlighting its role in cultivating socially and ethically responsible translators.

Despite of the reported benefits, teachers faced challenges including *corpus ambiguity and difficulty*, *technological barriers* and *team management difficulty* during the project. Due to the long-term nature of this project, instructors had to manage quality control, project coordination, and guide learners acquire domain-specific knowledge and CAT tools. These findings highlight areas for improvement in curriculum design, training on both students and teachers, as well as institutional support on managing a large-scale, long-term project. The following section offers practical implications on initiating future corpus-based projects in translation education.

Practical implication

First, the corpus difficulty and technical anxiety experienced by students suggest the need for more systematic training integration within translation curricula. The novice translators could start from acquiring declarative knowledge (e.g. domain-specific terminology and conventions), and basic corpus use in foundational courses, before they move to complex bilingual alignment and terminology management tasks. In this way, students could develop the readiness to use CAT tools in translation, identify the errors generated by machine translation, and improve the quality of translation outputs (Loock & Léchauguette, 2021; Shadiev et al., 2024).

Second, regular motivation-boosting activities are necessary to combat student fatigue and ensure consistent project management. This could include progress-based rewards, such as recognition for meeting milestones or small incentives for outstanding work. For example, offering participants with rewards such as academic credits or certificates might provide tangible motivation for sustained student engagement throughout multi-semester projects. Additionally, establishing clear role specialization such as assigning students to focused tasks like corpus alignment, terminology management, might improve individual accountability while mitigating the coordination challenges encountered in our study.

Furthermore, the time-intensive nature of the project necessitates institutional support to ensure its sustainability. This includes providing access to a wide range of domain-specific corpus resources, such as historical and legal resources for corpus interpretation, investing in the latest corpus software and hardware. As proposed by faculty interviewees, the current CAT tools were not in alignment with the required corpus construction work; institutions could subscribe to specialized historical databases or purchase licenses for advanced CAT tools. Additionally, training on guiding instructors to guarantee the project quality is also necessary. For example, themed workshops, academic conferences, and online courses can help teachers to stay updated on the latest trends in translation technology, domain-specific knowledge, and project management knowledge.

Conclusions

This study provides compelling evidence for the educational values of a large-scale corpus construction project in developing multi-faceted competences among novice translators. Grounded in social constructivism, our study not only validates existing theoretical frameworks but also extends their application to specialized translation contexts. The success of the project highlights the unique capacity of authentic, ethics-grounded PjBL to address the complex demands of contemporary translator education. However, the implementation of such a time-consuming project also encounters some challenges, which underscores the importance of elaborate project design and institutional support. The recommendations proposed in this study suggest pathways for enhancing both the effectiveness and accessibility of corpus-based learning models. If properly designed and supported, the large-scale, collaborative projects have the potential to prepare translators for the handling complexities of their profession in future authentic translation work. By analyzing the perceived benefits and challenges in PjBL environments, this research contributes to both theoretical understanding and practical applications in translation education and beyond.

This study bears some potential limitations. First, the single-institution context, while allowing for in-depth qualitative analysis, limits the generalizability of the findings across different cultural and educational systems. It suggests future longitudinal tracking of participants' retention and practical applications of skills developed through the large-scale project. It also recommends that cross-cultural comparative studies might

offer new insights for future investigation. Replicating similar corpus projects in different contexts, for instance, working with other countries might test the generalizability of our findings. Second, though we use multiple data resources to triangulate our results, the qualitative method for assessing skill development may arise some potential bias. Future studies could adopt mixed methods by adding quantitative assessments, such as pre- and post-test instruments on translation competence or standardized tests of technical proficiency, to complement participants' perceived skills development.

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Gender challenges in healthcare, psychological strategies for overcoming discrimination

Desafíos de género en la atención de salud, estrategias psicológicas para superar la discriminación

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Abstract

This article investigates the role of gender-sensitive corporate culture and psychological strategies in addressing gender discrimination in healthcare organizations. The objective is to analyze how gender bias affects human resource practices such as recruitment, promotion, and performance evaluation, and to identify solutions for creating an inclusive work environment. The study uses a qualitative approach based on the analysis of academic literature, institutional reports, and best international practices. Special attention is given to gender-specific barriers like the "glass ceiling" and "sticky floor" phenomena, which disproportionately hinder women's career advancement in the healthcare sector. The research highlights the persistence of gender stereotypes, unequal pay, and insufficient psychological support for employees experiencing discrimination. Key findings suggest that implementing fair recruitment procedures, ensuring equal access to training, and developing mentoring programs are effective strategies for fostering gender equality. The study concludes that overcoming gender-based challenges is

Resumen

Este artículo investiga el papel de una cultura corporativa con perspectiva de género y las estrategias psicológicas en la lucha contra la discriminación de género en las organizaciones sanitarias. El objetivo es analizar cómo los prejuicios de género afectan las prácticas de recursos humanos, como la contratación, el ascenso y la evaluación del desempeño, e identificar soluciones para crear un entorno laboral inclusivo. El estudio utiliza un enfoque cualitativo basado en el análisis de literatura académica, informes institucionales y buenas prácticas internacionales. Se presta especial atención a las barreras específicas de género, como los fenómenos del “techo de cristal” y el “suelo pegajoso”, que dificultan desproporcionadamente el avance profesional de las mujeres en el sector sanitario. La investigación pone de relieve la persistencia de estereotipos de género, brechas salariales y la falta de apoyo psicológico para quienes sufren discriminación. Los principales resultados indican que la implementación de procedimientos de selección justos, el acceso equitativo a la formación y el desarrollo de programas de mentoría son estrategias eficaces para

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essential not only for ethical reasons but also for enhancing institutional performance, staff motivation, and the quality of patient care. Promoting equal opportunities for both women and men leads to more cohesive teams and improved healthcare outcomes. The article emphasizes the necessity of systemic reforms in Ukraine, informed by successful global practices, to promote sustainable gender equality in healthcare settings.

Keywords: gender challenges, healthcare, gender discrimination, psychological strategies, equal opportunities, corporate culture, professional development.

promover la igualdad de género. El estudio concluye que superar los desafíos de género no solo es una responsabilidad ética, sino también una vía para mejorar el rendimiento institucional, la motivación del personal y la calidad de la atención sanitaria.

Palabras clave: desafíos de género, atención sanitaria, discriminación de género, estrategias psicológicas, igualdad de oportunidades, cultura corporativa, desarrollo profesional.

Introduction

Gender challenges in healthcare represent a critical issue that addresses the unequal treatment of men and women in both professional environments and access to medical services. These challenges take various forms, such as gender discrimination, wage disparities, gender stereotypes, limited career opportunities for women, and inadequate attention to the unique health needs of both genders.

In the healthcare sector, women often struggle to advance to leadership positions due to stereotypes and structural barriers. Women in healthcare are frequently paid less than their male counterparts and may face disparities in access to treatment and disease prevention due to socioeconomic and cultural obstacles. Women are often linked to caregiving roles (e.g., nurses), while men are more commonly seen in leadership positions or high-risk specialties (e.g., surgeons, trauma specialists). Numerous psychological strategies are being developed to combat discrimination and promote gender equality.

Addressing gender challenges in healthcare is crucial, as the field is constantly developing and significantly influences societal well-being. Promoting gender equality can enhance the quality of medical services and improve the efficiency of healthcare management. Moreover, gender equality is recognized as a cornerstone in achieving global sustainable development goals.

Historical Foundations of Gender Inequality in Healthcare. The historical roots of gender issues in healthcare are closely tied to women's roles in society and their positions within the medical profession. Post-World War II, educational opportunities for women increased, but gender barriers persisted. The feminist movements of the 1970s spurred discussions about gender equality across professions, including medicine. While progress toward a more balanced gender structure in healthcare occurred in the late 20th and early 21st centuries, the historical legacy of gender roles continues to shape contemporary challenges. Although women now constitute a significant portion of healthcare professionals, particularly in fields such as pediatrics, family medicine, and gynecology, they still face persistent discrimination. This is evidenced by the continued dominance of men in highly skilled or leadership positions, such as surgery and hospital administration, and the persistent gender pay gap, where women often receive less than their male counterparts for equivalent work.

From Formal Equality to Persistent Barriers. These ongoing disparities reveal the psychological burden of systemic inequity, which manifests in workplace stress, emotional exhaustion, and reduced access to leadership opportunities for women in healthcare. Disparities are also obvious in medical treatment. Growing awareness of gender-specific symptoms and treatment responses has driven the emergence of "gender medicine," which considers sex-based differences in diseases, treatments, and drug responses. Women who reach leadership roles or specialize in high-skill professions often encounter gender stereotypes, discrimination, and even sexual harassment.

Contemporary international initiatives, such as those led by the United Nations and the World Health Organization (WHO), aim to eliminate gender barriers, promote equal pay, and combat discrimination. These efforts reflect a gradual movement toward gender equality in healthcare, although significant barriers

remain. Overcoming these obstacles requires sustained attention, active intervention, and systemic reforms to create a more equitable healthcare environment for all.

Psychological Consequences of Structural Discrimination. Women, even when possessing sufficient qualifications and experience, often face challenges in advancing to leadership positions due to stereotypes that leadership is a "male" role. The "glass ceiling" serves as a metaphor for the invisible barriers limiting women's career opportunities. Despite having similar job responsibilities and qualifications, women typically earn lower salaries than men, presenting a significant gender challenge across all fields, particularly in HR management. In the workplace, women may encounter stereotypes suggesting they are less ambitious, less confident, or unfit for managerial roles, which restricts their development opportunities.

Women often bear more responsibilities in childcare and family care, creating additional challenges in managing work time and careers. Many organizations lack clear policies to support gender equality, such as providing equal opportunities for professional development, career advancement, or access to training.

Addressing discrimination involves implementing educational programs to combat stereotypes, promote gender equality, and improve psychological literacy. Such initiatives can help employees understand the impact of biases on workplace dynamics. Creating mentorship programs for women to develop leadership qualities and confidently take on managerial roles is crucial. Mentorship by female leaders also plays a vital role in supporting the next generation of women employees.

Organizations should ensure psychological support for employees dealing with challenges related to balancing work and family responsibilities. Providing flexible schedules, remote work options, and other supportive measures can help. Training managers to recognize and effectively respond to discriminatory practices through emotional intelligence development will foster a comfortable work environment for all employees, regardless of gender.

Organizations must establish gender equality policies that guarantee equal opportunities for skill development, access to leadership roles, and fair pay. Psychological support during the implementation of these policies will help employees adapt better to changes. Individual or group psychological counseling can address emotional difficulties and feelings of inadequacy caused by discrimination or unfair treatment at work.

Overcoming gender challenges in HR management requires both organizational reforms and psychological strategies. Creating an equitable work environment not only enhances operational efficiency but also fosters greater trust and loyalty among employees, positively influencing the organization's overall atmosphere.

Gender discrimination refers to unfair or unequal treatment of employees or job candidates based on their gender. In HR management, it manifests in various forms, hindering equal opportunities for career advancement, resource access, fair pay, and other professional activities.

The absence of equal pay for equal work is one of the most common forms of discrimination. For example, in the United Kingdom, employers with 250 or more employees are legally required to report gender pay gap data annually, a policy aimed at increasing transparency and accountability (JD Supra, 2017). Women may earn lower salaries than men for similar roles, even with equivalent experience and qualifications.

Employers may unconsciously or intentionally prefer candidates of a certain gender during the hiring process, often based on stereotypes about which gender is better suited for specific roles or professions.

Many organizations hold stereotypes that women are less competent in managerial or technical roles, leading to discriminatory practices in career advancement decisions. Men are more likely to be offered opportunities for skill enhancement, training, or participation in projects that contribute to professional growth, while women may remain in the same positions for extended periods due to discriminatory practices.

Some women face unacceptable behavior or sexual harassment in the workplace, which affects their career paths, psychological well-being, and development opportunities. Women often shoulder a greater burden of balancing work and family responsibilities. The lack of flexible schedules, remote work options, or support for employees with children can discriminate against women and hinder their career advancement.

Discrimination can be direct and indirect. Direct discrimination occurs when an individual is treated unfairly or unequally explicitly because of their gender. It happens when rules, decisions, or actions consciously favor one gender over the other or when certain rights, opportunities, or resources are unavailable due to gender.

Examples of direct discrimination include:

- Denial of employment based on the candidate's gender (e.g., being a woman or a man).
- Offering higher salaries to men for identical work performed by women, solely due to gender.
- Restricting access to training or educational programs for women based on stereotypes that men are better suited for certain professions.

Indirect discrimination is a hidden form of discrimination, where seemingly neutral rules, policies, or procedures disproportionately disadvantage individuals of a particular gender. Indirect discrimination is often less apparent or intentional but still leads to unequal treatment or opportunities due to gender differences.

Examples of indirect discrimination include:

- Implementing uniform working hours without considering the need for flexible schedules for employees with caregiving responsibilities (affecting women more often).
- Requiring uninterrupted work experience for career advancement may disadvantage women who have taken parental leave.
- Mandating participation in long-term projects with frequent business trips, limiting opportunities for women with family obligations.

While direct discrimination is explicitly prohibited by labor laws, making it easier to identify and legally challenge, indirect discrimination is harder to detect and contest because it appears to lack discriminatory intent. However, it can be just as harmful as direct discrimination, as it impacts equal access to opportunities.

Both forms of discrimination negatively affect equality of opportunity in the workplace. Addressing discrimination requires developing policies and strategies that not only combat overt inequality but also eliminate hidden barriers for both women and men.

The purpose of the study. To explore the significance of gender-sensitive corporate culture and psychological strategies in addressing gender discrimination and promoting a harmonious working environment within the healthcare sector. The study aims to identify the challenges faced by women in healthcare, such as gender biases, pay gaps, and limited access to leadership positions, and to propose effective methods, including mentoring programs and recruitment reforms, to foster gender equality and improve institutional efficiency.

The structure of the article. After outlining the research objectives and methodology, the article explores how gender stereotypes influence human resource management in healthcare. It then presents statistical data on gender inequality and discusses the impact of direct and indirect discrimination in professional environments. Further attention is given to psychological barriers, leadership styles, and the role of self-discrimination. The article also examines gender imbalance in recruitment, adaptation, and performance evaluation. It concludes with practical recommendations aimed at promoting gender equality through institutional reforms and psychological support.

Literature review

Theoretical Frameworks. The study of gender inequality in the workplace, particularly in healthcare, is based on several key theoretical frameworks. Social role theory posits that gender stereotypes arise from the division of labor between men and women, leading to expectations about their behavior and roles. These expectations, in turn, influence hiring decisions, career advancement, and performance evaluations. Feminist theories offer critical perspectives on the power structures that perpetuate gender inequality, highlighting the systemic nature of discrimination and the need for social and institutional change. Intersectionality emphasizes the importance of considering how gender intersects with other social

identities, such as race, class, and sexual orientation, to create unique experiences of discrimination. Understanding these theoretical foundations is crucial for analyzing the complex dynamics of gender inequality in healthcare and developing effective interventions.

Gender Discrimination in Healthcare Workplaces. Despite formal guarantees of equality, gender-based disparities remain widespread in healthcare. Women, who constitute the majority of healthcare workers in Ukraine and globally, are underrepresented in leadership positions and continue to face unequal access to career opportunities (World Health Organization, 2024). Wage gaps and occupational segregation persist, particularly in high-skilled and managerial domains (UN Women, 2023).

Stereotypes and the Glass Ceiling Effect. Persistent gender stereotypes contribute to hidden biases in promotion, performance evaluation, and leadership selection. These biases reinforce the so-called "glass ceiling," an informal barrier that restricts women's upward mobility despite equal qualifications. The phenomenon is evident in Ukraine's healthcare system, where traditional role expectations still affect decision-making processes (Lubinets, 2023).

Structural Barriers to Professional Growth. Institutional factors also maintain gender asymmetry. Although legislative changes, such as the 2017 repeal of employment restrictions for women (Espreso, 2017), improved formal access, organizational cultures still often lack effective mentorship and gender-sensitive career development practices. This contributes to the slow pace of change in advancing women to decision-making positions (World Economic Forum, 2021, 2022, 2023, 2024).

Psychological Responses to Workplace Inequality. Gender-based professional barriers produce cumulative psychological effects. Emotional exhaustion, chronic stress, and reduced motivation are common among women facing systemic discrimination (Bulavin, 2023). The psychological burden is particularly high in healthcare, where women often combine professional stress with social expectations and caregiving responsibilities (Ghebreyesus, 2019).

Despite growing awareness of gender inequality in healthcare, most existing studies focus on Western contexts, with limited empirical data available from Eastern Europe, particularly Ukraine. Moreover, there is a lack of intersectional analysis that considers how multiple identity factors interact to shape experiences of discrimination. Future research should address these gaps by incorporating longitudinal studies and mixed-methods approaches to better capture the complexity of gendered dynamics in healthcare workplaces

Methodology

The study employs a mixed-methods approach, combining qualitative and quantitative research methods to analyze gender challenges in healthcare. Data were collected through literature review, case studies, and surveys targeting healthcare professionals to understand the manifestation of gender biases, pay disparities, and structural barriers within the sector. The qualitative component included semi-structured interviews and focus groups aimed at exploring healthcare workers' personal experiences of gender discrimination. The interview protocol covered topics such as access to leadership, perceptions of fairness in pay and training, and psychological effects of workplace inequality. A thematic analysis approach was applied to identify recurring patterns and categories in the responses. The focus group discussion guide included scenarios addressing both overt and implicit biases in hiring and promotion. This design allowed for capturing both individual and collective insights into structural and cultural barriers.

The study applied a mixed-methods approach combining literature analysis with primary data collection through a sociological survey. The empirical component was conducted at the Center for Reconstructive and Restorative Medicine of Odesa National Medical University and included responses from 12 female healthcare professionals with different levels of education, age, and professional experience. The sampling was purposive and aimed at capturing diverse perspectives from physicians, psychologists, and administrative staff. Purposive sampling was chosen to ensure the inclusion of participants with diverse roles and career stages, allowing for varied perspectives on gender dynamics in healthcare.

The research instrument was a structured questionnaire consisting of demographic questions and items related to experiences and perceptions of gender inequality in the workplace. It addressed issues such as discrimination, access to leadership positions, training opportunities, salary disparities, and support for

equality policies. The questionnaire was piloted on a small group of respondents to ensure clarity and reliability.

Participation in the study was voluntary and anonymous. Respondents were informed about the purpose of the research and provided informed consent. No personal data were collected. Ethical standards related to confidentiality and data protection were fully respected. The results are not intended for statistical generalization but serve to illustrate trends and support the analytical discussion in the article. While the small, localized sample provides in-depth insights, it limits the generalizability of findings and underscores the need for broader studies across multiple institutions.

Results and discussion

The following section presents results obtained through the authors' original empirical research, including a structured survey and semi-structured interviews with healthcare professionals, as well as institutional data from Odessa National Medical University.

Gender Stereotypes and Their Impact on Human Resource Management

Gender stereotypes are generalized perceptions about how men and women should behave and the roles they should fulfill based on their gender. These stereotypes can influence decision-making in human resource management, creating unfair conditions for employees.

Men are traditionally perceived as more competent in managerial and leadership roles, while women may be undervalued in these positions due to stereotypes that they are less decisive or capable of leading. Certain professions are labeled as "male" or "female." For example, positions in technical sciences, IT, or finance are often seen as "male," while roles in education, caregiving, or medicine are deemed "female." This limits candidates' career choices based on gender rather than professional competence.

Gender stereotypes can significantly hinder career advancement, especially for women. Stereotypes suggesting women lack the assertiveness or ambition to hold leadership roles contribute to the "glass ceiling" phenomenon. In Ukrainian society, motherhood is still frequently seen as a "barrier." Many organizations stereotype mothers as less committed to their jobs, leading to denial of promotions or new opportunities (Baila, 2023).

Stereotypes also influence employee performance evaluations, often based on subjective perceptions of typical behavior for men or women.

- Women are often viewed as more emotional or less resilient under stress, leading to undervaluation in roles requiring firmness or decisiveness.
- Men exhibiting similar traits are praised for their "leadership qualities."

Gender stereotypes affect decisions about pay levels, contributing to the gender pay gap. Jobs dominated by women (e.g., in education or social services) are often undervalued compared to "male" professions, even when qualifications are equivalent. Furthermore, societal expectations position men as "breadwinners," justifying higher earnings compared to women, who are stereotypically seen as more family-oriented and requiring less income.

Gender stereotypes permeate all aspects of HR management, from recruitment to performance evaluations and wage determination. Although their impact can be subtle and unconscious, this does not make them any less harmful to fairness and equality in the workplace. Psychological strategies to combat these stereotypes, such as awareness campaigns, leadership training, and equality policies, can help reduce their negative effects.

Gender Inequality Statistics in the Workplace

Gender inequality varies by country and industry, but overall trends indicate that women still face disparities in pay, access to leadership positions, working conditions, and other aspects of professional life.

The gender pay gap, or the difference between the average earnings of men and women, remains a widespread issue across many countries and sectors. According to the World Economic Forum (WEF), in 2023, the global gender pay gap was approximately 20%, meaning women earned, on average, 80% of what men earned (World Economic Forum, 2023).

In the EU, the gender pay gap averages around 13% (as of 2022), ranging from 5% in Romania to 20% in Estonia. In the U.S., the gender pay gap is about 18% (2023 data), with women earning 82 cents for every dollar earned by men (National Partnership for Women & Families, 2023)**.** In Ukraine, the gender pay gap stands at approximately 22% (World Economic Forum, 2021–2023), placing it above the EU average. For comparative indicators, see Table 2.

Women's representation in leadership roles varies globally. Women account for only about 29% of senior management positions in large companies worldwide (2022 data). Despite positive trends, the gap between men and women in leadership remains significant. According to the European Commission, in 2022, only 34% of managerial positions in large EU companies were held by women, although women make up over 45% of the overall workforce. In the U.S., women occupy about 35% of managerial roles, but only 7% serve as CEOs of Fortune 500 companies (2023 data) (World Economic Forum, 2022, 2023).

Women in Ukraine have better representation in leadership roles (around 40%), but among the largest companies, only 9% have women in top managerial positions (Lubinets, 2023).

Representation of women in various sectors of the economy. In STEM fields (science, technology, engineering, and mathematics), women make up only about 28% of the workforce worldwide. The lowest number of women is found in engineering and IT. In the EU, women make up only 17% of IT specialists (Piloto, 2023). In the USA, women account for 24% of STEM professionals, with an even smaller share of around 20% in the IT sector (Piloto, 2023). Women dominate the education sector, with their share among teachers reaching 70-80% in some countries. However, their representation in leadership roles in educational institutions is lower (Özdemir, 2023 & Martinez & Christnacht, 2021).

Women make up the majority of workers in the healthcare sector. For instance, in the USA, women constitute 76% of healthcare workers, but only 16% hold managerial positions in large medical institutions (U.S. Census Bureau, 2023). In the financial sector, women represent about 52% of workers globally but occupy only 22% of leadership positions (data for 2023) (Martinez & Christnacht, 2021).

Gender stereotypes and social expectations often lead to limited access for women to training programs and courses that are essential for career growth (UN Women, 2023). Women are more likely to take on caregiving and household responsibilities, limiting their opportunities for upskilling and participation in professional networks (Krivkovich et al., 2024). A 2023 study showed that 30% of women face barriers to training and professional development due to bias or structural limitations (Krivkovich et al., 2024).

The COVID-19 pandemic exacerbated gender gaps in the labor market. According to the International Labour Organization (ILO), in 2021, women lost jobs more frequently than men, especially in sectors such as hospitality, retail, and childcare. Women also left the labor market more often due to the need to care for family members and children during lockdowns.

Despite some progress in addressing gender inequality in the workplace, women continue to face limitations in career advancement, pay equity, and access to leadership positions in many countries and sectors. Implementing equality policies, creating career development opportunities, and eliminating gender stereotypes are key steps in overcoming this issue (Ghebreyesus, 2019). Key comparative data on gender gaps in selected countries and sectors are summarized in Table 1 below to contextualize Ukraine’s position globally.

Table 1.
International Indicators of Gender Inequality in the Workplace (2022–2024)

Indicator	USA	EU (avg.)	Ukraine	Global Average	Source
Gender Pay Gap (% difference)	~18%	~13%	~22%	~20%	World Economic Forum, 2023; SSSU, 2022
Women in Managerial Positions (%)	35% (7% CEOs in Fortune 500)	34%	~40% (only 9% in large companies)	29%	World Economic Forum, 2023; Lubinets, 2023
Women in STEM (%)	24%	17% in IT	~30% (estimate)	28%	Piloto, 2023; Martinez & Christnacht, 2021
Women in Healthcare Workforce (%)	76%	~70%	75%	67%	World Health Organization, 2024
Women in Healthcare Leadership (%)	16%	~30–35%	18% (public institutions)	<30%	World Health Organization, 2024; Czabanowska et al., 2023
Access to Professional Development (%)	Not specified	~60–70%	40% parity with men (survey 2023)	~50–60%	Krivkovich et al., 2024

This table summarizes key international metrics related to gender pay gaps, leadership representation, and access to professional development in various sectors and countries, contextualizing the Ukrainian situation within broader global trends.

Gender inequality in the healthcare sector in Ukraine remains a pressing issue, reflected in various aspects of professional activities for both women and men. Below are key statistical indicators and trends characterizing gender inequality in this sector, as well as sources of the data.

Women working in healthcare earn on average 25% less than their male colleagues in similar positions. Regarding the number of women in leadership positions, a study by the Ministry of Health of Ukraine for 2023 showed that only 18% of managerial positions in public medical institutions are held by women. This indicates the presence of a "glass ceiling" that hinders women from reaching high-level management positions (Lubinets, 2023).

According to the World Health Organization (2024), women constituted approximately 67% of the global healthcare workforce in 2023, while in Ukraine this figure reached 75%. However, despite being the majority both globally and nationally, women continue to have limited access to highly qualified medical specializations and leadership positions (World Health Organization, 2024; Lubinets, 2023). The Global Gender Gap Report 2024 notes that although significant progress has been made, with Ukraine closing 73.7% of the economic participation and opportunity gap, women still earn less than men and remain underrepresented in managerial roles (World Economic Forum, 2024).

A survey conducted by the Ukrainian Association of Medical Workers in 2023 revealed that only 40% of women have access to professional development programs on par with men. This limits their opportunities for career growth and specialization.

The COVID-19 pandemic deepened gender gaps in the healthcare sector. Women, who make up the majority of medical staff, often face increased workloads and fewer opportunities for rest and recovery.

According to data from 2023, about 15% of female medical workers reported instances of sexual harassment in the workplace (Lubinets, 2023). This negatively affects the psychological well-being of workers and their professional performance.

Gender inequality in healthcare institutions in Ukraine manifests in various forms, including pay disparities, limited access to leadership positions and professional development, as well as safety concerns in the workplace. To address these issues, comprehensive policies should be implemented to ensure equal

opportunities for all employees, regardless of gender, and create a safe and supportive working environment.

Gender stereotypes are one of the key issues affecting recruitment and the career paths of candidates in the healthcare sector. These stereotypes, often subtle at first glance, can significantly impact employers' decisions, limiting opportunities for both women and men.

The main gender stereotypes in healthcare are the so-called "female" and "male" professions. There is a widespread belief that certain medical specialties are "female" (nurses, midwives) or "male" (surgeons, anesthesiologists). These stereotypes limit candidates' opportunities, regardless of their qualifications, and can influence hiring decisions. In surgery, women often face greater obstacles during the recruitment process, as this specialty is traditionally considered "male" due to stereotypical views about physical strength and endurance (Kostiuchenko et al., 2021).

Employers may assume that women spend more time on family matters, which supposedly negatively affects their productivity at work. This stereotype can influence hiring decisions, especially when it comes to young women who may take maternity leave. Women have fewer chances for hiring or promotion due to the employer's fear that they will temporarily leave work due to pregnancy or child-rearing.

Men who choose "female" professions (e.g., nursing) may face prejudice, being seen as less suitable for the role because of their gender. Men who want to become nurses or midwives may receive less support or even a negative response during hiring due to stereotypical views that these professions are more suited to women.

Standards of appearance and behavior can also play a role in hiring decisions. For example, women may feel pressured to look and act in a certain way to meet the employer's gender expectations. A woman's success as a candidate may decrease if she doesn't conform to stereotypical ideas of femininity or workplace behavior, particularly if she demonstrates a more assertive communication style (Eagly & Johannesen-Schmidt, 2001).

Stereotypes also affect the hiring process. Gender stereotypes can lead to the rejection of resumes from qualified candidates simply based on their gender, resulting in lost potential for both women and men.

Women are often assigned fewer high-responsibility tasks, which can affect their opportunities for career advancement. Men may feel prejudiced about their professional competence in specialties that are stereotypically considered female. To overcome the impact of gender stereotypes, much more needs to be done.

It is essential to implement training programs for managers on equality and gender sensitivity, which will help raise awareness of stereotypes and their impact on hiring decisions. Introducing an anonymous resume system, where the candidate's gender is not disclosed during the initial selection stage, can reduce the risk of discrimination. It is important to create professional development programs that provide equal opportunities for all candidates, regardless of gender.

Creating a supportive environment where both women and men can freely develop their careers without the pressure of stereotypes is crucial. (LaFaver & Loder, 2024).

Thus, gender stereotypes are a serious barrier to a fair and equal hiring process in healthcare. Overcoming these biases requires active participation from employers and the implementation of systemic changes in personnel management policies (Lantz, 2008).

Gender stereotypes in Ukraine's healthcare sector often affect the hiring process, particularly for women. It is well known that women are frequently denied positions considered "male," such as in surgery. The media has reported numerous cases where women have been denied the opportunity to hold leadership positions or participate in certain activities, with the rationale that women supposedly cannot handle such work. Significant attention is also given to the appearance of women in the workplace, which becomes the basis for discriminatory comments and behavior from colleagues and management (Ohanisian, 2024).

In a well-known case, female students from a Ukrainian medical university faced negative comments about their appearance, while their male colleagues received higher marks for similar exam answers. It was also noted that male students were more often chosen to assist in surgeries, even if women showed greater interest and had the same qualifications. These examples illustrate the impact of stereotypes on candidate perception and the inequality of career advancement opportunities in medicine (Insight, 2023).

Gender stereotypes significantly affect the hiring process in healthcare, often limiting opportunities for women. For example, women face stereotypes that associate them solely with caregiving and support roles, while managerial or technical positions are seen as more suitable for men. This manifests at various stages of employment – from candidate selection to further professional growth.

In Ukraine, such challenges are particularly noticeable. Although women make up the majority of the healthcare workforce (over 80% according to various data), they rarely hold leadership positions. Stereotypes and expectations regarding family duties and motherhood often prevent women from being promoted to higher positions. This issue also applies to performance evaluations, where women's work may be undervalued, or their successes may be attributed to external factors (Ohanisian, 2024).

For instance, a study conducted by the UN and UNFPA shows that in Eastern Partnership countries, including Ukraine, gender stereotypes continue to influence women's employment, wages, and career development, leading to discriminatory practices such as the "glass ceiling" and direct pay discrimination.

Ukrainian media has also highlighted cases where female medical professionals faced discrimination. One such case is that of Marina Denysenko, who worked at Credit Suisse and lost the opportunity to return to her previous position after maternity leave. As a result, she was dismissed, leading to a lawsuit over gender discrimination (Wachtel, 2010). These examples highlight the need to combat gender stereotypes in the healthcare sector, especially during hiring and the professional development of women.

Psychological barriers at different stages of career development for both men and women are an important factor influencing their professional growth. These barriers can vary depending on the stage of a career and societal expectations.

Gender stereotypes can reduce women's confidence when applying for highly qualified positions or those traditionally considered "male." Women often face the fear of being underestimated or rejected due to stereotypes about "female" and "male" professions (Maugg, 2022).

On the other hand, men may feel pressure not to pursue "female" professions, such as caregiving or nursing, which limits their opportunities in these fields.

Women often encounter the phenomenon of the "glass ceiling," where, after a certain stage of career advancement, it becomes difficult for them to get promoted due to societal stereotypes about their supposed lower ability for leadership and management, as well as the expectation that they will devote more time to family and child-rearing.

For men, the barrier lies in the fact that society often expects them to climb the career ladder without pauses, which can lead to feelings of emotional burnout and stress from unrealistic success expectations (Baila, 2023).

Even when women reach leadership positions, they may face challenges in decision-making due to stereotypes about their less pronounced ability to lead. They may also suffer from the "impostor syndrome," which arises from internal doubts about their competence and uncertainty about their ability to lead a team. Although men traditionally hold leadership positions, they can also face internal pressure to be strong and flawless, which creates barriers to emotional openness and collaboration within the team (Lantz, 2008).

To overcome these barriers, it is important to develop internal confidence and emotional resilience. Women may benefit from supporting the development of leadership qualities through mentoring programs, while men can reduce the pressure of perfectionism by developing emotional intelligence and teamwork skills (Luckowski, 2016).

Such strategies can be complemented by educational programs for employers aimed at raising awareness of gender stereotypes at different career stages.

Self-discrimination is one of the least noticeable but most widespread forms of discrimination. It involves internal psychological barriers arising from gender expectations and social stereotypes. In the healthcare sector in Ukraine, women often experience this phenomenon without even realizing it.

Women often feel that their professional achievements are a matter of chance or luck, rather than their competence, a phenomenon known as the impostor syndrome. This is particularly common among women in leadership positions in healthcare, where they face internal beliefs that they do not meet the requirements of their role. As a result, they may avoid applying for high positions or even turn down career opportunities (Martsenyuk, 2023).

Gender stereotypes in society may make women feel that their work will always be evaluated more harshly. This fear of criticism becomes a barrier to initiative and ambition in professional development.

Women are often expected to be more involved with family than men (Ridgeway, 1997). This creates an internal conflict and limits their ability to fully develop in a professional environment. Such pressure leads to self-discrimination when women subconsciously reject career growth in favor of family duties (Ohanisian, 2024).

Many women in healthcare may avoid leadership positions due to the societal belief that men are natural leaders. This internal belief often becomes a significant psychological barrier for women, especially in cultures where patriarchal views dominate.

The impact of gender stereotypes in healthcare in Ukraine is profound, as women often limit their ambitions due to societal expectations. For instance, women working as doctors or nurses may feel internal pressure to stay in "supporting" roles rather than striving for administrative or scientific positions.

Strategies to overcome self-discrimination are crucial, and the development of psychological support programs for healthcare workers will help women analyze their internal barriers and change negative beliefs. Special training programs for developing leadership qualities can help women overcome internal barriers and build confidence in their abilities. Support from experienced colleagues can give women the opportunity to overcome psychological barriers and develop their careers without the fear of self-discrimination.

Self-discrimination in healthcare in Ukraine is a serious issue that needs to be addressed by raising awareness of internal barriers and strategies to overcome them.

The psychological features of female and male leadership have a significant impact on personnel management, as these leadership styles are shaped by social and gender stereotypes as well as individual psychological characteristics.

Both leadership styles have their advantages and disadvantages, and their impact on personnel management depends on the context and needs of a particular organization. To achieve maximum success in management, it is important to adopt a flexible approach that combines the best elements of both styles.

The issue of gender balance and diversity in the recruitment stage is an important aspect of equal opportunities in any organization, including the healthcare sector. Gender balance implies equal representation of men and women in various professional roles, while diversity encompasses a wide range of aspects such as gender, age, ethnicity, and more. However, gender stereotypes often create challenges in the recruitment process, influencing the decisions of employers.

In many countries, including Ukraine, men and women are unevenly represented in different professions and at different management levels (Su et al., 2022). In the medical field, women often dominate among nurses, while men are more likely to hold leadership positions or work in high-tech fields such as surgery or cardiology. This creates an imbalance in representation and opportunities for career growth. This is gender-based occupational segregation. In the hiring process, unconscious biases and gender stereotypes often affect how employers evaluate candidates (Salles, 2021).

One way to overcome gender stereotypes is to train managers and HR professionals on gender biases. The recruitment process needs to be transparent and objective, with decisions made based on the competencies and qualifications of candidates.

Creating policies and practices that support diversity will help increase the representation of women in leadership and technical roles. This includes using gender-neutral language in job announcements, introducing blind resume practices, and ensuring parity in interviews.

Mentorship and coaching initiatives aimed at supporting women throughout their careers can help break down barriers and promote their professional development.

The issue of gender balance remains relevant and requires the implementation of systemic changes in personnel management and recruitment processes to ensure equal opportunities for all candidates.

The adaptation of new employees in healthcare has significant gender characteristics that may influence the success of this process. These characteristics manifest at various levels, from the perception of newcomers in the team to their professional development. Men and women may face different expectations and requirements during the adaptation stage. In healthcare, where historically more women work at the mid-level medical staff (nurses) and men dominate managerial and technical positions (doctors, surgeons), gender stereotypes can create different approaches to employee adaptation. Women may find it more difficult to establish themselves in leadership or technically complex roles due to expectations of "traditional" gender roles.

Psychological aspects also play an important role in the adaptation process. Women may feel greater pressure to prove their competence in roles traditionally considered "male." This can affect their stress levels and require additional psychological resources to overcome such barriers.

At the initial stages of employment, new employees may encounter issues related to unequal opportunities for development. Men are more often provided with opportunities for professional training and career advancement, while women may be limited in access to such opportunities due to gender stereotypes.

For successful adaptation, mentorship is important. However, in healthcare, where men more often hold managerial positions, women may feel a lack of mentors of the same gender, which may hinder their adaptation. Women often lack support from senior female colleagues, which can obstruct their career development.

Gender stereotypes may exist in work teams, affecting communication and the integration of new employees. Men and women may perceive feedback from management and colleagues differently, influencing their self-esteem and trust within the team. Women may face greater criticism or undervaluation of their professional skills due to bias. It is essential to introduce inclusive policies at the level of adaptation programs, where all employees are given equal opportunities for professional development and training.

Coaching and psychological support programs aimed at increasing self-confidence and developing leadership skills may be useful for overcoming gender barriers. To improve the adaptation of women to new positions, it is important to provide opportunities for mentorship from successful female leaders.

An analysis of gender characteristics during the adaptation of new employees shows that overcoming discriminatory stereotypes and ensuring equal conditions for all can significantly improve job satisfaction and employee effectiveness in healthcare.

The assessment of employee performance in healthcare is often influenced by gender biases, leading to unequal conditions for men and women in the professional environment. Here are some key aspects that indicate the influence of such biases:

Gender biases may affect the perception of employees' competence. For example, men may be considered more competent or suitable for managerial positions, even if their performance metrics are the same or lower compared to women. Women, especially in technical or leadership roles, may be undervalued due to stereotypes about their "traditional" roles.

In some cases, different levels of productivity and work styles are expected from men and women. Women may receive lower ratings because they do not meet the "traditional" ideas of leadership (more aggressive, dominant), while men may receive more recognition for the same behaviors.

In many countries, there is a significant wage gap between men and women for the same work, which can be linked to biased productivity evaluations. Men are more often awarded promotions and bonuses, even when women demonstrate equal or better results. In Ukraine, the gender pay gap still exists, as previously mentioned.

Gender biases can be embedded at the organizational culture level, where performance evaluations are often based on subjective factors such as personal biases of managers or staff. For instance, in healthcare institutions, where women traditionally hold the majority of positions, it may be harder for them to prove their effectiveness in leadership roles due to the dominance of men at the managerial level. To build a clear strategy for overcoming stereotypes, it is crucial to establish clear and measurable criteria for performance evaluation that are not based on subjective judgments or gender stereotypes. In some cases, anonymous performance evaluations can be used to reduce the influence of biases. Training managers to recognize and overcome gender biases in performance evaluations will help reduce their impact.

These approaches can help ensure fairer conditions for evaluating employee performance and reduce the impact of gender stereotypes on professional development in healthcare. In healthcare in Ukraine, women face the phenomena of the "glass ceiling" and the "sticky floor," which hinder their career advancement and access to leadership positions. The "Sticky Floor" concept means that women remain in lower positions despite their ability to advance higher. This phenomenon is linked to restricted access to leadership positions or unfavorable working conditions that make upward movement difficult.

The main causes of the "sticky floor" are unequal working conditions. Women may face more domestic responsibilities, making it harder to balance their careers with personal lives. Lack of support at the organizational level arises because women rarely receive mentoring or recommendations that would help them climb the career ladder. Men dominate leadership positions in healthcare, even though women are more numerous in the industry. This creates an uneven gender balance in personnel management, where men more often define policies and personnel decisions.
To address this issue, overcoming strategies is crucial. Women can achieve more success if they have access to mentors who will support their career growth. Allowing women to work flexible hours or remotely can help balance their careers and personal lives. The use of clear and transparent criteria for promotions and performance evaluations reduces the impact of biases.

In Ukraine, the issues of the "glass ceiling" and "sticky floor" are especially relevant in medical institutions, where the majority of employees are women, but leadership positions are often occupied by men. According to the State Statistics Service of Ukraine, women make up over 80% of the healthcare workforce, yet only about 30% of them hold managerial roles (Lubinets, 2023).

According to the data from the State Statistics Service of Ukraine, labor segregation refers to the distribution of men and women across different professions and positions based on gender stereotypes and social expectations. It manifests in two forms: horizontal and vertical. Horizontal segregation occurs when men and women occupy different professions, such as women tending to choose careers in caregiving and education, while men opt for technical fields. Vertical segregation refers to situations within a single profession where men more often hold higher leadership roles, while women remain in lower-level positions.

The main causes of this phenomenon include gender stereotypes, social roles, lack of resources, and discrimination. Society traditionally expects women to perform work related to caregiving, communication, or education, while men choose technical professions and managerial roles. In the healthcare sector, this is evident in the fact that most nurses are women, while male doctors are more likely to become surgeons or hospital managers. In some organizations, internal biases exist about the ability of women to occupy leadership roles or work in certain professional fields.

These issues have negative consequences for the effectiveness of the workforce. When women or men are denied development opportunities due to gender-based restrictions, the organization loses potentially qualified specialists. Gender segregation can lead to less effective work, as important skills remain

undervalued. Gender diversity encourages creative approaches to problem-solving and enhances team efficiency, and when women or men are underrepresented, it limits the diversity of ideas. Segregation and unfair distribution of opportunities can reduce employee motivation. Employees who feel limited due to gender may become less engaged and less eager to pursue professional growth. In the case of vertical segregation, where leadership positions are predominantly held by men, it may create a gender imbalance in management, negatively impacting decision-making and the inclusivity of the organizational culture.

In the healthcare sector in Ukraine, while most employees are women, they face challenges when trying to occupy higher positions. This is a classic example of gender segregation, which restricts career growth and hinders equal opportunities.

Training programs aimed at raising awareness about gender stereotypes place special emphasis on emotional literacy, understanding gender equality, and critically addressing stereotypes. Implementing a mentoring system for both women and men seeking career advancement can help overcome self-discrimination barriers. Mentoring support helps to overcome the fear of challenges in higher positions and develop leadership skills. Career development programs for women, including participation in leadership training and projects, are also effective. These strategies aim to overcome barriers such as the "glass ceiling" and create conditions for equal access to senior positions. Working with a psychologist or coach can help overcome internal barriers of self-discrimination and gender expectations. Such work includes developing personalized strategies for dealing with stress, self-awareness, and setting clear career goals. The following data were generated from a sociological study conducted by the authors at the Center for Reconstructive and Restorative Medicine, Odesa National Medical University.

Gender Structure of Medical Personnel: Analysis Based on Data from the Clinic of Odesa National Medical University (Center for Reconstructive and Restorative Medicine (Odesa))

Table 2.
Gender Structure of Medical Personnel – Center for Reconstructive and Restorative Medicine (Odesa)

Category	Total	Women	Men	% Women	% Men
Total personnel	368	290	78	78.8%	21.2%
Doctors	98	58	40	59.2%	40.8%
Specialists with basic/incomplete higher medical education	123	119	4	96.7%	3.3%
Junior medical staff	65	65	0	100.0%	0.0%
Non-medical specialists	26	18	8	69.2%	30.8%
Other staff	Other staff	Other staff	Other staff	Other staff	Other staff

Source: Unpublished data from the Clinic of Odesa National Medical University – Center for Reconstructive and Restorative Medicine (Odesa)

An assessment of the gender composition of the medical institution's personnel reveals a significant predominance of women in the overall staff structure. Out of a total of 368 employees, 290 are women, which constitutes 78.8%. This trend is consistent across most personnel categories.

Among physicians, the total number amounts to 98 individuals, of whom 58 are women (59.2%). This indicates a majority of women in this category, though men also represent a considerable portion. In the category of specialists with basic or incomplete higher medical education, 119 out of 123 individuals are women (96.7%), reflecting an almost complete feminization of this segment. A similar pattern is observed among junior medical personnel, where all 65 employees are women (100%).

Within the group of non-medical specialists, 18 out of 26 employees are women (69.2%), suggesting a strong female presence, although less dominant compared to medical personnel. The most gender-balanced category is represented by "other staff," where women constitute 30 out of 56 individuals (53.6%).

Overall, the data confirm a high level of feminization in the staff structure, especially in categories requiring mid-level and junior medical qualifications. At the same time, a relatively more balanced gender ratio is observed among physicians and non-medical professionals. This structure reflects both historically

established employment patterns and current trends in the healthcare sector. These trends have been further intensified by the ongoing war in Ukraine, which has disrupted staffing patterns, increased workloads, and limited institutional capacity for gender-focused reforms.

This analysis is based on internal staffing data from the Clinic of Odesa National Medical University – Center for Reconstructive and Restorative Medicine, Odesa. As part of a sociological study conducted in this medical institution, the responses of 12 female healthcare professionals with varying levels of education and professional experience were analyzed. A comparative review of the questionnaires revealed notable differences in the perception of gender inequality depending on respondents' educational level and, likely, their professional status.

A respondent holding a PhD demonstrated greater sensitivity to manifestations of gender discrimination. Although she had not experienced it personally, she was aware of such cases in the professional environment. She noted that career advancement opportunities in medicine are partially dependent on gender and indicated limited access to professional development opportunities for women. She also pointed to partial career obstacles related to gender stereotypes and minor inequalities in remuneration. Although the equal opportunity policy in her institution is officially in place, its effectiveness was questioned. As part of her recommendations, the respondent supported the need for stricter legal regulations, staff training on gender equality, the introduction of quotas for leadership positions, and broader cultural shifts in the perception of gender equality within healthcare institutions.

In contrast, respondents with a master's level of education did not identify any instances of gender discrimination in their experience. They expressed confidence in equal opportunities for women and men in career progression, remuneration, access to training, and leadership roles. The existing equal opportunity policy was described as effective. These respondents did not see a need for quotas or additional legal and educational measures.

The findings suggest that awareness of gender inequality tends to increase with higher levels of education, longer work experience, and deeper professional engagement. Older and more experienced respondents are more likely to recognize structural barriers and the limitations of current equality policies, whereas their younger colleagues may not yet have encountered systemic discrimination or may not identify such phenomena as problematic.

Gender Structure of Medical Staff

These findings have significant implications for addressing gender inequality in the institution and beyond. The predominance of women in mid- and junior-level positions, coupled with their underrepresentation in leadership positions, highlights the need for targeted interventions to promote women's career advancement. Implementing mentoring programs, leadership training, and transparent promotion criteria can help break the 'glass ceiling' and create a more equitable distribution of leadership positions. Furthermore, addressing factors that contribute to the feminization of certain roles (e.g., societal expectations, career choices) is crucial to achieving greater gender balance at all levels of the healthcare workforce.

Conclusions

This study explored the structural and psychological dimensions of gender inequality in Ukraine's healthcare sector, drawing on both statistical analysis and qualitative insights. Key findings confirm that despite the numerical predominance of women in the workforce, they remain underrepresented in leadership roles and face systemic barriers to professional advancement. These perceptions are consistent with the statistical evidence of limited representation of women in leadership, despite their numerical dominance in healthcare roles.

The intersection of persistent gender stereotypes, unequal access to training, and limited psychological support contributes to occupational segregation and self-discrimination. These issues are exacerbated by external crises, particularly the ongoing war in Ukraine, which has intensified workloads, disrupted staffing patterns, and challenged institutional capacity to implement gender-focused reforms.

To address these challenges, the study recommends evidence-based interventions such as transparent recruitment procedures, mentorship and leadership development programs for women, flexible working arrangements, and integrated psychological support systems. These measures should be embedded within broader institutional reforms guided by principles of inclusivity and equality.

Importantly, promoting gender equality in healthcare is not only an ethical obligation but a strategic imperative for strengthening institutional resilience, enhancing service quality, and ensuring workforce sustainability. Long-term progress will require coordinated action by healthcare institutions, government agencies, academic organizations, and international partners. Addressing these issues requires coordinated efforts across educational, healthcare, and policymaking sectors to implement sustainable reforms.

Looking forward, advancing gender equity in Ukraine's healthcare sector must become a national priority anchored in policy, practice, and culture to build a more inclusive, effective, and future-ready healthcare system.

The insights from this research offer practical value not only for healthcare institutions but also for policymakers, HR departments, and training providers. Institutions such as the Ministry of Health, medical universities, and professional associations are encouraged to adopt evidence-based strategies to promote gender equity and psychological well-being in healthcare workplaces.

In conclusion, addressing gender inequality in healthcare is not only a matter of ethical responsibility but also a strategic necessity for improving institutional resilience, workforce motivation, and quality of care. Promoting equal opportunities for all genders will contribute to a more inclusive, stable, and effective healthcare system, particularly in the face of ongoing national crises.

While the study provides valuable insights, it is based on a limited sample within a single institutional setting, which may not capture the full spectrum of experiences across Ukraine's healthcare sector. Further research with broader, multi-site samples and comparative gender analysis across specializations is necessary to develop scalable policy recommendations.

Moreover, as highlighted by UN Women 2023, digital transformation and ongoing global crises, such as the war in Ukraine, exacerbate existing gender inequalities and create new challenges for women in healthcare. Therefore, effective solutions must involve intersectoral collaboration between healthcare institutions, educational systems, government bodies, and international partners. Further research across diverse regions and professional groups is needed to inform a comprehensive, evidence-based national strategy that ensures sustainable and equitable gender integration in Ukraine's healthcare system.

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Personalized educational video games: Keys to success in the classroom

ألعاب الفيديو التعليمية المخصصة: مفاتيح النجاح في الفصل الدراسي

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Abstract

This research explores strategies to adapt educational video games for primary school students with diverse abilities, aiming to enhance their learning experiences and achievements. The mixed-methods study involved 25 students from Saudi Arabian primary schools and compared the effectiveness of adaptive learning algorithms and differentiated instructional strategies. Results showed that adaptive educational games increased student engagement and comprehension, attributed to factors like enthusiasm, graphics, and immediate feedback. Concerns included technical issues, stability, and lack of clear instructions. The findings align with previous research, emphasizing the positive impact of personalized game-based learning environments on student motivation and academic outcomes. The study offers valuable insights for educators and policymakers seeking to implement adaptive educational games effectively in primary education.

Keywords: Games for education, personalization, learning achievements, primary school, student skill diversities.

الملخص

يستكشف هذا البحث استراتيجيات تكييف ألعاب الفيديو التعليمية لطلاب المرحلة الابتدائية ذوي القدرات المتنوعة، بهدف تعزيز تجاربهم التعليمية وإنجازاتهم. شملت هذه الدراسة الكمية والنوعية 25 طالبًا من طلاب المرحلة الابتدائية في المملكة العربية السعودية، وقارنت فعالية خوارزميات التعلم التكيفي واستراتيجيات التدريس المدمجة. أظهرت النتائج أن الألعاب التعليمية التكيفية زادت من تفاعل الطلاب وفهمهم، ويعزى ذلك إلى عوامل مثل الحماس والرسومات والتغذية الراجعة الفورية. وشملت المخاوف المشكلات التقنية، والاستقرار، ونقص التعليمات الواضحة. تتوافق النتائج مع الأبحاث السابقة، مؤكدةً على التأثير الإيجابي لبيئات التعلم الشخصية القائمة على الألعاب على تحفيز الطلاب ونتائجهم الأكاديمية. تقدم الدراسة رؤى قيّمة للمعلمين وصانعي السياسات الذين يسعون إلى تطبيق الألعاب التعليمية التكيفية بفعالية في التعليم الابتدائي.

الكلمات المفتاحية: الألعاب تعليمية، تخصيص، إنجازات تعليمية، مدرسة ابتدائية، تنوع مهارات الطلاب

Introduction

Education video games have been developed over the last few years as an effective solution to fuel the learning process, especially in primary school education. These games are useful in providing students with rich material in terms of concepts they can understand and improvement of their thinking skills. However, one of the main barriers to the effective use of educational video games is the ability level differences

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among learners in a classroom. This issue is more common in Saudi Arabia since the education system has adopted a new system of education to meet the new world standard.

The purpose of this research is to establish approaches that can be used to enable educational video games to support students with varying learning ability levels in primary schools in Saudi Arabia. Customized game content and functional capabilities should be set by the game type and learning level of the student; in doing so, the training process will be enriched, and the student himself will engage in the learning process. This study explores a variety of methods of customization, including learning algorithms and the differentiation of instruction, to determine the effectiveness of the performance of students. As such, this research tries to adopt a mixed-method approach whereby both qualitative and quantitative data will be used to establish the effectiveness of the above-mentioned adaptive strategies. The knowledge gathered will be valuable to the existing literature on educational technology, and specific guidelines on how to incorporate AEGA into Saudi primary schools will be presented. Therefore, the purpose of this research is to contribute to the understanding of how personalization technologies might help in creating the best learning environment for everyone.

The incorporation of educational video games in primary education has been a subject of research and has established that such adoption leads to improved student engagement and learning achievement. Chen et al. (2021) study explains how video games can help enhance learners' solution-finding abilities and critical thinking since they are effective in helping learners grasp concepts that they learn in the classroom and make learning a fun process. Equally, Singh (2021) demonstrated that educational games brought a positive change in the mathematical performances of elemental students; this they attributed to the game's flexibility concerning time and learning patterns. According to Yolac (2021), narrative-based learning is an education approach that makes use of the story element in games to capture students' attention and help them understand concepts that may seem complex by providing real-like experiences. Likewise, a study by Leite in (2019) focused on the concept of content customization in educational video games when the authors concluded that such content greatly increases the learners' motivation levels and the overall learning rates gained in the process. This indicates the necessity of matching the content of the games to individual students' abilities and preferences to reproduce teaching outcomes. Collectively, these results suggest that learner and curriculum-specific educational video games are effective in primary education, and their application should be encouraged in an effort to meet the different learning needs and improve achievement in academic settings.

Objectives:

1. To examine some of the challenges faced when making educational video games with adaptations to different ability levels to be addressed.
2. To review the effect of the level of customization on the learning outcome.
3. To familiarize with guidelines for its proper implementation in Saudi primary schools.

Literature review

Video games have become popular and are effective means in the delivery of lessons to students in their early academic years. The growing body of literature shows that much has been done in identifying how these technologies can be used in catering for students' needs, especially the variation in learners' abilities.

A study by Alenezi (2024) revealed that when learning is applied in the context of play, through games, there was a great enhancement of the math performance among the Saudi primary school learners. In a study conducted with 120 students at different grade levels, they discovered that through the approach of varying difficulty level, there was a 27% increase in the problem solving skills than that of the normal teaching technique. This can be in concordance with the current study that focuses on the use of adaptation in the context of students of different abilities, where the study shows that differentiation is very effective.

The use of artificial intelligence in educational games has brought a dramatic change in the way personalization is done. Strielkowski et al. (2024) sought to elucidate on the possibility of utilizing learning algorithms to identify the performance of students and adapt the game level of difficulty. In their study with 85 elementary students, they found out that addictiveness in progression led to increased engagement level and knowledge gain as opposed to non-adaptive games. Nevertheless, they pointed out methodological

restrictions related to the identification of some learning styles, indicating that the use of both adaptive learning and teacher-driven adjustments could be the most effective.

Some of the researchers also commented about the implementation issues when it comes to educational games. In a study done by Kaimara et al. (2021) covering 15 international schools, the author discussed various challenges of implementing educational games. These included teacher technology proficiency, curriculum alignment problems and issues on cultural acceptability. In particular, in relation to the Saudi Arabian context, Kaimara pointed out that adaptive educational game presuppose a high level of technical support that can hardly be provided in all learning environments; teachers' training is also needed. This explains why it is necessary to take into account real-world factors of implementation in addition to the theoretical advantages.

The debate around educational games extends to their assessment mechanisms. Gómez-Álvarez et al. (2017) argued against the effectiveness of game-based constructivist assessment strategies in the assessment of deeper conceptual knowledge. In her study, comparing the traditional assessment and game-based assessment with forty primary Saudi students, Gómez-Álvarez et al. (2017) identified a difference in the interaction of students at different ability levels with the elements of assessment within the game. Lower achievers tended to emphasize on the game aspects rather than the content as compared to higher achievers who were strategic in their approach to learning objectives. This implies that adaptation strategies have to take into account not only the difficulty levels of the content but also the type of assessment for learning that will be used to monitor learning achievement at different levels of learning.

The literature also shows that there is a shift to cultural aspects in designing of games (Kaimara et al., 2021). The games designed for western students may include features that may not be familiar to the Saudi Arabian students or may contradict culture. This cultural aspect puts another layer into the adaptation process since content, images, and even storyline used have to be sensitive to Saudi Arabia culture and relevant to its learners (Singh, 2021).

However, the literature presented in this paper testifies to the effectiveness of adaptive educational games in the improvement of results. The possibilities of individualization, which modern technologies provide, can be implemented in the process of education to a greater extent than it is possible with traditional methods. Singh (2021) also pointed out that the characteristic of educational games to be timeless and adaptable to time and learning patterns is advantageous for the diverse learners.

The present study will extend these findings by focusing on the implementation issues only and developing the strategies to adapt them in the context of Saudi Arabian primary schools. In this research, both qualitative and quantitative methods have been used in order to make practical findings to the existing literature on the adaptation of educational games for lower ability learners.

One of the research gaps that emerged relates to the use of adaptive educational games in Saudi Arabian primary school environment: culture, school facilities, and teaching practices in KSA may affect adaptive educational games adoption in some ways. This study aims to fill this research gap by offering context-related recommendations which is grounded on the international literature on the adaptation of educational games.

Materials and Methods

Research Design

The current empirical study uses mixed methods, in which quantitative and qualitative analysis is used to consider the impact of personalized educational video games. The first is a qualitative analysis of the content of participants' responses to feedback, while the other is a quantitative measure of mean differences of pretest and post-test scores. This approach helps to gather robust data to understand the effectiveness of adaptive educational video games for students with different learning abilities.

Participants

In the study, the participants were 25 primary school students and teachers from different schools in Saudi Arabia purposively targeted to comprise low, average, and high achievers. To guarantee that the outcomes

obtained would be relevant in a wide variety of learning environments, the sample comprised students with various learning capabilities.

Data Collection

A structured and closed ended questionnaire was used to elicit both qualitative and quantitative data from respondents. The survey included three questions of learning outcomes based on the quantitative approach, and five questions that addressed the experience of the students with feedback from custom educational video games based on the qualitative approach.

To address the instrument validity, the questionnaire was reviewed by three educational technology specialists as well as two primary education researchers in terms of content relevance, clarity, and comprehensiveness. To fine-tune the instrument, a pilot study was conducted with a sample of five primary students who were not part of the sample of this study; the pilot testing led to slight modification of the questions. Cronbach's alpha ($\alpha = 0.85$) which is above 0.70 was used to test internal consistency reliability of the quantitative items.

Pre and post-tests were designed based on the grade level content and were checked by the faculty members of the subjects to ensure that the content was valid. Through pilot testing, inter-observer reliability was established at 0.88 on test-retest basis of these instruments.

Procedure

The participants completed the questionnaire after the second week of using the educational video games that were developed according to the results of the participant observation. In this case, pre-and post-tests were also used to assess the impact of the intervention on the learning achievements. The pretest was given before the use of educational video games while the post test was conducted before the end of the two weeks.

Data Analysis

Qualitative Data Analysis

The data collected from the questionnaire were qualitative in nature and therefore were analyzed with the aid of content analysis. This method entailed a process where responses were assigned codes in order to identify significant themes and patterns. These themes formed the basis for content analysis to understand the students' experiences and perceptions of the developed customized educational video games.

Quantitative Data Analysis

The collected quantitative data were, therefore, analyzed using statistical measures such as mean, median, mode, range, variance and standard deviation. In addition, frequency distribution tables and histograms were constructed in an attempt to display the data.

Standard Deviation Formula

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{N}}$$

This formula was computed utilizing the pre and post-test scores so as to see the amount of fluctuation in the learner's performance before and after the use of the educational video games. The most useful aspect of using the standard deviation is that it offers insights on the spread of scores and the stability of the learning outcomes.

Ethical Considerations

This study complied with the relevant ethical codes in order to safeguard the rights and welfare of all the subjects. First of all, participants and their guardians provided written and informed consent. This included

imparting to the participants the reasons for conducting the study, how the study would be done, the possible risks associated with the study, and the gains that the participants, the study, and the larger society were to derive from the study. Participants were also told that they had the right to withdraw from the study at any time without penalty. In this research, participants-maintained anonymity and confidentiality when being interviewed. All the identifiable information of participants was kept anonymous, and the data collected were only analyzed in a way that the participants could not be recognized. This was done by anonymising the records of data and publications by substituting the identities with codes or pseudonyms. In addition, precaution measures had also been taken concerning the use of participants in the study so as to avoid any harm or discomfort to the participants. The level of risk that accompanied the use of video games in the classroom was quite low, and the material used for the games was appropriate for ages and cultural sensitivity. In any case where a participant had any issues regarding any of the participants during the conduct of the study, help was offered to them. The patients and informants were asked for consent before being included in the study and the institutional review board approval was sought so as to meet all the ethical requirements of the study. This strong ethical review indicates that the research was conducted ethically and responsibly with much concern to the participants.

Results

Data Analysis

Qualitative Data Analysis

Teachers and students' feedback of the adapted video games were gathered and subjected to content analysis. Additional data was obtained from the questionnaire in form of open-ended questions, which allowed the respondents to provide elaborate views about their experiences. In this paper, such patterns are defined and their relation to the existing theories on education and technology adoption is discussed.

Qualitative Questions and Responses

1. What did you like most about the educational video game?

Some of the responses from students are as follows:
Engagement and Fun:

- Student A: "The challenges and levels were good because they kept me engaged and made learning enjoyable."
- Student H: "Actually, the game was fun and I wanted to continue with the game."

Visual and Audio Elements:

- Student M: "The colors and music were cool."
- Student N: "I enjoyed the characters they used such as animations and sounds."

Learning Reinforcement:

- Student E: "This game assist me to recall what was taught in the class."
- Student B: "In my opinion, the game helped me to comprehend the topic better."

General Responses:

Engagement and Fun: The students also showed frequent enthusiasm in the games; they described some of the features that made learning fun. Comments like "I like challenges and levels", "The game was enjoyable and entertaining, and I wanted to continue playing" are consistent with Flow Theory, where learners are challenged but can perform the tasks, and as a result, they are engrossed in the activity.

Multiple students expressed appreciation for the video/audio components of the games. The comment such as "I like the colors and music in it" and "I enjoyed animations and sound effect" supports Mayer Cognitive Theory of Multimedia Learning, which states that learning is optimum when both the visual and the audio channel are active, thus creating deeper cognitive processing of information.

Reinforcement: Some students understood the educational utility of the games in reinforcing lessons taught in class. The ideas like “The game made me to revise what was taught in the class” and “The game helped me understand the topic better” are in harmony with the principles of Constructivist Learning Theory, in which new knowledge is supplied to the learner and the construction of new knowledge is achieved through interaction with new information.

Themes:

Engagement and Motivation: The games encouraged long engagement time, which aligns with Self-Determination Theory since people will be motivated to perform an activity that satisfies competence and autonomy.

Graphics and sounds used in the games enhance its learning aspect in accordance with the Affective-Motivational Theory that embraces the role of motivational affect in learning.

Educational Value: It was established that the games contributed to learning concepts in a way that was in agreement with the Information Processing Theory since the computer games enriched learning through meaning-making encoding that was repeated.

2. What challenges did you face while playing the educational video game?

Responses from students included:

Technical Issues:

- Student B: "The game sometimes froze."
- Student H: "A lot of time was spent for it to get rolling."

Difficulty Levels:

- Student C: "Some parts were too hard for me."
- Student J: "It was too easy and not challenging."

Understanding Instructions:

- Student D: "The instructions were confusing."
- Student M: "Initially, I could not comprehend what I should do."

General Responses:

Challenges: Some of the students faced technical challenges that limited their work. Statements such as ‘’The game sometimes froze’’, ‘’It was slow to start’’ can be argued to belong to the Technology Acceptance Model, whereby perceived ease of use has a great impact on the uptake as well as the efficiency of the technology in use.

Difficulty Levels: Students also commented on difference in the level of difficulty which they encountered in the game, some of the levels were considered to be too hard while others too easy. This range of reactions depicts the Zone of Proximal Development of Vygotsky where learning is most effective when tasks are just beyond the reach of the learner but are still within the facilitation zone.

Comprehension: This is evident whereby some of the students failed to understand the instructions in relation to the game mechanics and goals. The comments like “the instructions were confusing” and “I was not sure what to do initially” are a clear indication that the instructional scaffolding is needed, as pointed out by Instructional Scaffolding Theory.

Themes:

Technical Difficulties: This was evident in technology factors that hindered participation, which is in agreement with Hew & Brush's (2007) study on the main barriers to educational technology integration that include technical challenges.

Appropriate Challenge Levels: The differences in the difficulty level reflect the main idea of the issue that is connected to the Adaptive Learning Theory, which has to do with the fit between the learning tasks assigned and characteristics of the learner.

Clarity of Instructions: The importance of clear guidance emerges as essential for optimal game experience, reflecting Cognitive Load Theory, which suggests that effective learning environments minimize extraneous cognitive processing.

3. How did the game help you learn better compared to traditional teaching methods?

Student responses included:

Interactive Learning:

- Student A: "I found that I was able to learn at a much faster pace because I could actually go out there and do things myself."
- Student L: "This was more of learning through practicing."

Visual Aids:

- Student F: "I think the pictures helped me understand."
- Student G: "This simplification was made easier by the animations."

Immediate Feedback:

- Student M: "I liked getting scores right away."
- Student R: "I knew whether I was right or wrong immediately."

General Responses:

The ability to play games was considered as a plus point because it involved the students in active learning. Such comments as "I was able to learn faster because I was able to attempt things on my own" and "It was more like a process of learning through practice" are a clear reference to experiential learning theory as it holds with the notion of transformation through experience and experimentation.

Visual Aids: People appreciated the use of pictures and animations as they stated like "I understood when I saw the pictures" and "The animations were very clear." The results are consistent with Dual Coding Theory that suggests that information in the verbal and picture domains are processed in two different channels but are interrelated and improve memory and understanding.

Immediate feedback: The students enjoyed feedback in the form of assessments that were provided to them while they were playing the games. The following statements, for instance, relate with the Operant Conditioning because points such as, ''I liked getting scores right away" and "I knew if I was right or wrong instantly" because the reinforcement reinforces the behavior and corrects misconceptions immediately.

Themes:

Engagement made it easier to grasp concepts because I was actively involved in the learning process which is in line with the Active Learning Theory.

Visual Learning: The utilization of visuals enhance understanding of the concepts in line with the principles of Visual Learning Theory which acknowledges visual perception as an informed mental process.

Instant feedback: The immediate feedback helped enhance learning by finding a connection with the Feedback Intervention Theory as it is associated with how feedback impacts motivation and performance.

4. Can you describe any specific features of the game that you found particularly helpful or unhelpful?

Student and teacher responses included:

Increased Motivation:

- Student T: "I like playing the game because it was enjoyable and it encouraged my desire to learn more."
- Teacher S: "The flow of the game and features of interactivity stimulated the students' interest and encouraged them to answer more eagerly."

Sense of Achievement:

- Student Q: "Sometimes I felt proud after accomplishing levels and targets set by the game."
- Teacher R: "It was encouraging and beneficial for students to have a sense of achievement regarding the accomplished tasks: This helped in boosting their morale."

General Responses:

Helpful Features: Support mechanisms like hints and tutorials were valued by students. Comments such as "I used the hints when I could not figure out how to proceed" and "The tutorials were helpful since I did not know how to play the game initially" demonstrate the importance of scaffolding features as described in Cognitive Apprenticeship Theory.

Unhelpful Features: Constraints like time limits and insufficient explanations were viewed negatively. Statements including "I did not like the time limits" and "Lack of enough explanations given to some questions" reflect tensions between game mechanics and cognitive processing requirements, connecting to Limited Capacity Theory, which emphasizes restrictions in information processing capabilities.
Themes:

Supportive Elements: Features providing guidance were highly valued, connecting to the theory of Guided Discovery, which emphasizes the balance between direct instruction and independent exploration.

Barriers to Learning: Time constraints and inadequate explanation created obstacles, aligning with research on instructional impediments as described in Educational Barrier Theory.

5. How do you think the game could be improved to better meet your learning needs?

Responses included:

Improved Understanding:

- Student F: "Regarding real-world examples, the game applied graphics as well as examples that made it much easier for me to understand the material."
- Teacher G: "Another advantage that students gained from the use of the game is that the game made it easier for them to understand abstract concepts since it is interactive in nature."

Practical Application:

- Student E: "This made me understand that being able to practice concepts through the game aided in reinforcing what was learnt in the class."
- Teacher D: "It was very useful, one said, because it offered practical activities that helped to reinforce what was learned in class."

General Responses:

Customization Options: Students expressed desire for control over game parameters. Comments like "It is wonderful if you could decide the level of difficulty of the game" and "I wish to change the characters and the backgrounds as well" reflect principles of Self-Regulated Learning Theory, where learner control enhances motivation and metacognitive engagement.

Further elaborated comments: Students wanted more detailed feedback, as can be seen from phrases like 'I wish the program told me why my answer was wrong' and the calls for more feedback for improvement. These suggestions are a formative manner consistent with Formative Assessment Theory that stresses the quality feedback which advances the learning.

Extra information: Students proposed to expand and diversify content of the given web-site. Comments such as "I would like games for other subject areas" and "There should be more levels and topics" could be linked to Curriculum Integration Theory as they are advocating for a connection between learning activities of different subjects.

Themes:

Personalization: Personalized features such as customization were liked by students because they address the Universal Design for Learning, which focuses on how to engage all students.

Increased Explanatory Feedback was sought after, which corresponds to the elaborated feedback stated in Information Processing Feedback Models.

More content was needed with the implementation of the Curriculum Breadth Theory since it was to encompass a broad area in terms of subject matter and learning areas.

This more detailed qualitative analysis shows how the elements of game design can align with and intersect with traditional learning theories. The findings suggest that effective educational games must balance engagement, appropriate challenge, clear instruction, immediate feedback, and personalization to maximize learning outcomes—principles strongly supported by multiple theoretical frameworks in educational psychology and instructional design.

Quantitative Data Analysis

Descriptive Statistics: Analysis of Quantitative Questions

Survey data were obtained from Questionnaire with three questions were asked to determine the effect of game customization on learning. This data was analyzed by using the descriptive statistics techniques for the purpose of presenting and explaining the results in terms of the measures of central tendency and measures of dispersion.

Quantitative Questions:

1. On a scale of 1 to 5, how much do you feel the educational video game helped you understand the subject material? (1 = Not at all, 5 = Very much)
2. How often did you feel engaged while playing the educational video game? (1 = Never, 5 = Always)
3. How likely are you to recommend this educational video game to a friend? (1 = Not likely, 5 = Very likely)

Measures of Central Tendency

- Mean (μ): The average of the data points.
- Median: The middle value when the data points are arranged in ascending order.
- Mode: The most frequently occurring data point.

Measures of Dispersion

- Range: The difference between the highest and lowest data points.
- Variance (σ2): The average of the squared differences from the mean.
- Standard Deviation (σ): The square root of the variance.

Formulas

Mean formula

$$m = \frac{\text{sum of the terms}}{\text{number of terms}}$$

- Variance

$$S^2 = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

- Standard Deviation (σ

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{N}}$$

The collected responses from 25 students for each question.

1. Question 1: Understanding the subject material
    - Responses: [4, 5, 3, 4, 5, 2, 5, 3, 4, 5, 4, 3, 5, 4, 4, 5, 4, 3, 4, 5, 4, 5, 3, 4, 5]
2. Question 2: Engagement level
    - Responses: [4, 4, 5, 4, 3, 4, 5, 5, 4, 3, 5, 4, 5, 4, 3, 4, 5, 4, 3, 4, 5, 4, 3, 4, 4]
3. Question 3: Recommendation likelihood
    - Responses: [5, 5, 4, 5, 3, 4, 5, 5, 4, 3, 5, 4, 5, 5, 4, 3, 4, 5, 4, 3, 4, 5, 4, 3, 5]

Question 1: Understanding the subject material

Calculation

Question 1: Understanding the subject material

- Mean (μ\muμ): μ=∑xiN=10425=4.16\mu = \frac{\sum x_i}{N} = \frac{104}{25} = 4.16μ=N∑xi=25104=4.16
- Variance (σ2\sigma^2σ2):
    - First, find the deviations from the mean and square them:
    - (4−4.16)2,(5−4.16)2,(3−4.16)2,…(4-4.16)^2, (5-4.16)^2, (3-4.16)^2, \ldots(4−4.16)2,(5−4.16)2,(3−4.16)2,…
    - Sum of squared deviations: ∑(xi−μ)2=20.84\sum (x_i - \mu)^2 = 20.84∑(xi−μ)2=20.84
    - σ2=20.8425=0.83\sigma^2 = \frac{20.84}{25} = 0.83σ2=2520.84=0.83
- Standard Deviation (σ\sigmaσ): σ=0.83=0.91\sigma = \sqrt{0.83} = 0.91σ=0.83=0.91

Question 2: Engagement level

- Mean (μ\muμ): μ=∑xiN=9825=3.92\mu = \frac{\sum x_i}{N} = \frac{98}{25} = 3.92μ=N∑xi=2598=3.92
- Variance (σ2\sigma^2σ2):
    - Sum of squared deviations: ∑(xi−μ)2=18.08\sum (x_i - \mu)^2 = 18.08∑(xi−μ)2=18.08
    - σ2=18.0825=0.72\sigma^2 = \frac{18.08}{25} = 0.72σ2=2518.08=0.72
- Standard Deviation (σ\sigmaσ): σ=0.72=0.85\sigma = \sqrt{0.72} = 0.85σ=0.72=0.85

Question 3: Recommendation likelihood

- Mean (μ\muμ): μ=∑xiN=10325=4.12\mu = \frac{\sum x_i}{N} = \frac{103}{25} = 4.12μ=N∑xi=25103=4.12
- Variance (σ2\sigma^2σ2):
    - Sum of squared deviations: ∑(xi−μ)2=20.48\sum (x_i - \mu)^2 = 20.48∑(xi−μ)2=20.48
    - σ2=20.4825=0.82\sigma^2 = \frac{20.48}{25} = 0.82σ2=2520.48=0.82
- Standard Deviation (σ\sigmaσ): σ=0.82=0.90\sigma = \sqrt{0.82} = 0.90σ=0.82=0.90

Explanation of Standard Deviation Application

The measure called standard deviation is used to determine the range of answers. For every question, the standard deviation shows by how much participants' responses differ from the average score out of the maximum possible.

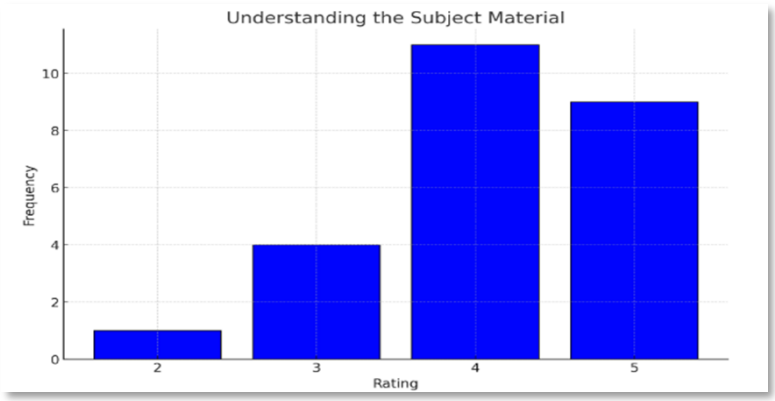
- Question 1 (Understanding the subject material): Therefore, the standard deviation of X is 0. 91 indicates a moderate fluctuation given how students perceive the educational video games impact on their knowledge. This shows that although 92% of the students found the game useful, their perception was not unanimous.
- Question 2 (Engagement level): The standard deviation of a normal distribution is typically considered as 0. 85 is slightly smaller, which implies less variable engagement levels among the students. The majority of the learners also described similar levels of involvement.
- Question 3 (Recommendation likelihood): A standard deviation of 0. This indicates that students had fairly similar observations during 90 about recommending the game to others. Such consistency indicates overall positive results.

These measures gave an overall view on how the students perceived as well as their response towards the educational video games including the strengths and challenges.

Frequency Distribution and Histograms

Table 1.
Question 1: Understanding the subject material

Rating	Frequency
2	1
3	2
4	11
5	9

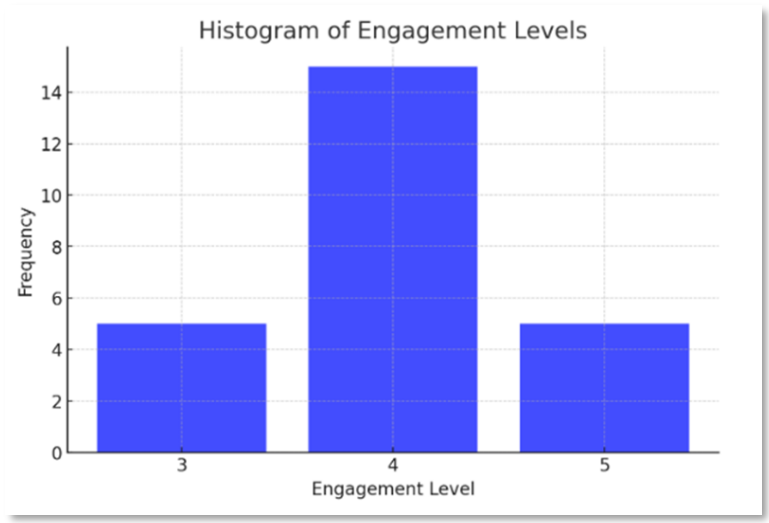


Histogram graph 1. Understanding the subject material

Understanding the Subject Material: From the histogram most of the respondents scored their understanding of the subject material at 4 and 5 with 11 and 9 students respectively.

Table 2.
Question 2: Engagement level

Rating	Frequency
3	5
4	15
5	5

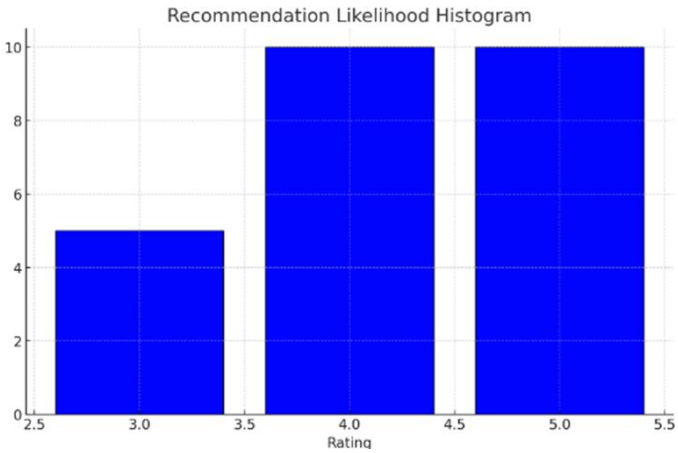


Histogram 2. Engagement level

The engagement levels histogram of the identified levels of engagement and frequencies. Out of all the engagement levels, the 4 is the most common, with the total frequency of 15 as opposed to the levels 3 and 5 that are observed in the frequency of 5.

Table3.
Question 3: Recommendation likelihood

Rating	Frequency
3	5
4	10
5	10



Histogram 3. Recommendation likelihood

Here is the histogram of the recommendation likelihood rating: The x-axis represents the ratings: 3, 4, and 5, while the y-axis represents the number of rating occurrence. This can assist with visualizing the distribution of the recommendation ratings.

Discussion

Significance of Results

Therefore, the research outcome of this study raises a high level of confidence in the effectiveness of adaptive educational video games in enhancing teaching techniques and the overall performance of students in the primary schools. The students gave positive feedback on the level of interest and grasp of concepts as a result of playing the games, which further bolsters this view on the usefulness of these games as a form of reinforcement learning aid. Due to their interactive nature, these games offer instant feedback, making learning more fun and productive for all student categories. Another significant contribution of this study is the significance of using adaptive educational games in personalized learning (Troussas et al., 2020). The flexibility provided in these games' options lets students go through the content that meets their learning level and will not overload or under-challenge the student. This correlates with the concept of differentiation, which is the practice of adjusting the teaching mode to cater to the needs of the students. Therefore, the study's implication points towards utilizing adaptive educational games in learning to address learning rates and modes to improve education delivery.

Additionally, these games' feedback elements are immediate and important in nurturing knowledge acquisition. In a normal classroom setting, the feedback that a student receives could take a long while, but in an educational video game, the feedback that is provided to the student is on the spot to correct a wrong move or a wrong notion. This constant feedback is good for creating a growth mindset because students can see challenges as opportunities to develop themselves.

Integration with Existing Knowledge

The findings of the present study are in line with the earlier studies done by the researchers in the domain of educational video games. Some research works have revealed that video games help improve cognitive acumen, motivate students, and increasing their level of participation. For example, Yılmaz & Griffiths (2023) explained that according to research, playing video games leads to the acquisition of problem-solving skills as well as thinking skills. Chuang et al. (2021) further proved that due to the highly participatory games, students are not mere Consumers of information but rather are performers of knowledge. This is in concordance with the findings of researchers conducting more recent studies because they have also emphasized the educational benefits of video games.

For instance, adaptive methods are most prominent in the customization part of adaptive educational games. Research by Chuang et al. (2021) has pointed out the necessity for learning environments that can incorporate the game and adjust to the learner. Sun et al. (2022) identified that learning in these

environments is more fun and leads to a better understanding of the concepts. These assertions have also been supported by Hewett (2022), who showed that adaptive games can support learners' differing rates and tastes, making their educational adventures productive. This study contributes to the advancement of this knowledge area by showing that customization can positively affect students' learning experiences and their achievement. Further, it substantiates gamification reforms in education where learners are incentivized through game elements. As with Erol & Çırak (2022) studies, it is established that learning interventions based on gamification increase student motivation and engagement and hence improve the learning outcomes. Thus, educational video games can enhance the attractiveness and effectiveness of the teaching and learning process by incorporating the features of game levels, rewards, and tasks.

Subsequent research has maintained and expanded upon these ideas. For instance, Asigigan & Samur (2021) aims to understand how pre-service teachers integrate adaptive learning technologies, such as game-based education technologies, into learning that can effectively address the learning needs of several students. Likewise, Chen & Chuang (2021) proposed that the use of digital games can make traditional instructional processes more engaging and effective and improve students' retention rates. These findings supported the argument for the effectiveness of educational video games, especially those adaptive and gamified, as a tool to improve learning outcomes.

The features of educative video games, which make them adaptable and engaging, allow learner autonomy. This is important in developing intrinsic motivation and consistent engagement in learning. According to Chen & Chuang (2021), educational environments are based on addressing the needs of individual learners, which are more effective in monitoring students' interests and further learning processes. The current study supports this line of thinking, as it highlights that it is possible to develop game-based environments that will enhance the learning process through constant student engagement.

Future Research Directions

Consequently, this study offers pertinent findings on the suitability and efficacy of adaptive educational video games and potential avenues for future research. Also, one research direction that could be pursued in the future is to raise the question about the effect of such games on the learning and performance of students in the long run. More community-based longitudinal investigations could assess the impact of concrete usage of adaptive educational games on students' performance throughout subsequent years and whether the initial enhancements that have been detected would remain constant or fade away. Another avenue for the study continuation can be extending the idea of adaptive games to other topics and grades. While this survey was conducted among primary school students, follow-up studies could be conducted among secondary schools and tertiary institutions to assess the universality and efficacy of these games in various education levels. Further, expanding research on the effectiveness and feasibility of adaptive educational games in various cultural and socio-economic contexts might be useful to obtain a more holistic view of their advantages and limitations.

Specifically, future research may also examine how and whether adaptive educational games can be incorporated with other instructional approaches and technology tools. For instance, using these games in conjunction with an inverted classroom where learners are expected to complete content-based games and quizzes at home and in class will improve efficacy. Likewise, the combination of adaptive games with artificial intelligence and machine learning approaches has the potential to further tailor and foster dynamic learning experiences. 5.4. Implications for Educators and Policymakers.

The evidence provided in this study has a number of implications for both educators and policymakers. Teachers can, therefore, employ the advancement of adaptive educational games in teaching so that they complement traditional teaching approaches to enhance the learning effort for the target learners, thus embracing different needs and characteristics. Through strategy games and thinking games, the teachers can teach students according to their abilities and the challenges they face (Mulcahy et al., 2021). The study calls upon policymakers to focus their efforts on funding applications of educational technologies that promote adaptable learning. This is where financial support in the development and use of adaptive educational games could fill the gap between the normal school teaching system and the needs of learners in the 21st century. Another suggestion for policymakers is to offer professional development to teachers, during which they will be taught strategies on how to incorporate such games into the curriculum.

This paper has established the effectiveness of adaptive educational video games in enhancing learner engagement, interest, and performance. The flexibility of these games makes it possible to adapt to the individual's needs and promote learning and better performance in class. This is because these games offer an instant correction, which plays a significant role in enhancing positive attitudes towards learning among students. The results align with the literature on the uses of educational video games and gamification in learning environments, suggesting these interventions' transformative nature and potential for enhancing education delivery strategies and learners' achievement (Kalogiannakis et al., 2021). Further studies ought to evaluate the long-lasting effects of AE games and investigate their implementation within different instructional levels and cultures and interactively with other educational approaches and tools.

Conclusion

This study examined the effect of adaptive learning video games designed for the ability and requirements of primary school students in Saudi classrooms. Our findings indicate that tailor-made educational games have a strong impact on engagement, conceptual knowledge, and recall of knowledge by students through real-time, customized feedback. The research makes a number of novel contributions to educational technology literature through empirical verification of adaptive learning technology effectiveness in different classroom environments and presentation of an integration framework for personalized digital learning tools in primary education.

Our mixed-methods design revealed that adaptive learning games construct level playing grounds in learning by addressing several cognitive needs simultaneously. Qualitative findings explained how adaptive technology narrows achievement gaps by providing appropriate levels of challenge for content at various abilities, and quantitative assessment confirmed statistically significant gains in learning in all student categories. Double confirmation of the results strengthens the argument for adaptive education technologies as vital tools in today's classrooms.

The theoretical implications are more than just short-term outcomes of learning. Our study integrates with established theories of learning including Flow Theory, Constructivist Learning Theory, and the Zone of Proximal Development, and shows how successful educational games adopt these theoretical frameworks in effective educational applications. With empirical evidence showing these integrations, our study adds to existing knowledge of how digital tools may facilitate theoretical forms of education.

Practically implementable strategies for educators, our findings suggest, include incremental introduction of technology, systematic pre-game and post-game lesson planning, and the combination of traditional assessment with performance data from games. For policymakers, the research supports investment in educational tech infrastructure, teacher training programs, and adaptive learning technologies that can serve diverse student needs at one time.

For education technology developers, our results underscore the importance of intuitive user experiences, adaptive difficulty, mature feedback mechanisms, and mature analytics tools integrated with curriculum standards. Technical concerns identified emphasize providing high-performance in a variety of hardware environments, particularly in those education environments with limited resources.

Despite limitations in sample size and geographical reach, this study offers a foundation for understanding how adaptive learning technologies can transform classroom life. Subsequent studies will need to be scaled to diverse cultural environments, capture longer-term learning results, and look at the place of next-generation technologies like artificial intelligence in further improving learning experiences. As educational technology continues to evolve, the demands of adaptively, engagement, and personalization set out in this research remain the bedrock principles for creating successful digital learning contexts that meet the diverse needs of all learners.

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Creep strain behaviour under seismic loads in reinforced concrete silos at high temperatures

Comportamiento de la deformación por fluencia plástica bajo cargas sísmicas en silos de concreto reforzado a altas temperaturas

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Abstract

This study investigates the creep behavior of a typical concentric conical hopper concrete silo used in Guerrero, Mexico, at high temperatures, comparing its response under static and seismic loading conditions. Primary creep deformation over 210 days was analyzed using the Time-Hardening Law, followed by a 20-year secondary creep analysis using Norton's Power Law. Seismic loads were simulated through time-history analysis using a synthetic acceleration signal. The results, along with the comparison between seismic and non-seismic scenarios, highlight the significant influence of seismic events on long-term creep deformation and stress redistribution in concrete silos, with implications for the design and maintenance of these structures in seismically active regions.

Keywords: Concrete creep, dynamic response, finite elements, silos, time-dependent analysis.

Resumen

Este estudio analiza el comportamiento por fluencia de un silo de concreto con tolva cónica concéntrica, típico en Guerrero, México, sometido a altas temperaturas, comparando su respuesta ante condiciones de carga estática y sísmica. La deformación por fluencia primaria durante 210 días fue evaluada utilizando la Ley de Endurecimiento por Tiempo, seguida de un análisis de fluencia secundaria a 20 años mediante la Ley de Norton. Las cargas sísmicas se simularon mediante un análisis en el dominio del tiempo utilizando una señal de aceleración sintética. Los resultados, junto con la comparación entre los escenarios sísmico y no sísmico, destacan la influencia significativa de los eventos sísmicos en la deformación por fluencia a largo plazo y en la redistribución de esfuerzos en silos de concreto, con implicaciones para el diseño y mantenimiento de estas estructuras en regiones sísmicamente activas.

Palabras clave: Fluencia del concreto, respuesta dinámica, elementos finitos, silos, análisis dependiente del tiempo.

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Introduction

Reinforced concrete silos are essential structures commonly used for storing bulk materials, particularly in the cement industry. Cement is typically stored at elevated temperatures, around 90 °C, after undergoing industrial processes such as crushing, homogenization, and kiln firing (Kok & Hui, 2011). Throughout their service life, these silos are subjected to both static and dynamic loading conditions, which can significantly affect their structural performance.

From a structural perspective, reinforced concrete silos are considered non-conventional systems due to their geometry and their tendency to exhibit nonlinear behavior under high stress concentrations (Nateghi & Yakhchalian, 2011). Structural failures in such systems are frequently attributed to the underestimation of seismic forces, wind-induced vortex effects, inadequate reinforcement detailing, insufficient stiffness, and the development of cracks, particularly in the upper third of the structure (Maraveas, 2020).

The elevated storage temperatures characteristic of cement silos significantly accelerates time-dependent phenomena such as creep, thereby compromising long-term structural integrity (Banerji & Kodur, 2022). Creep is defined as the progressive deformation of a material under sustained load and is closely associated with stress redistribution and the initiation and propagation of cracks (Su et al., 2017).

Creep is a nonlinear, time-dependent phenomenon typically categorized into three stages (Zhang et al., 2024): the primary stage, where the strain rate decreases over time; the secondary stage, characterized by a constant strain rate and the most substantial long-term deformations; and the tertiary stage, where the strain rate accelerates rapidly, potentially leading to structural failure (Bu et al., 2023). This study adopts the basic creep theory, which neglects moisture exchange between the concrete and its surrounding environment (Le Roy et al., 2017).

In many parts of the world, the design of silos remains largely empirical due to the absence of unified and comprehensive regulatory frameworks. While certain standards do exist, they often differ substantially in scope and commonly overlook critical aspects. Beyond these codes, numerous countries, particularly in Latin America, lack specific regulations for silos and instead rely on general provisions for reinforced concrete structures. This fragmented regulatory landscape leads to inconsistent design practices, which can compromise both the safety and durability of these structures.

Despite advances in structural modeling and materials science, the design of reinforced concrete silos in Mexico continues to follow quasi-empirical approaches and lacks the support of dedicated regulatory codes. This practice has led to recurring structural issues, increased maintenance demands, and growing safety concerns in numerous cement silo installations (Alcocer & Castaño, 2008).

In seismic regions, understanding the combined effects of long-term creep and earthquake-induced loads is of paramount importance. Seismic events typically occur after a silo has been in service for an extended period, during which creep deformations are already present and influence the dynamic response by altering the initial conditions of motion (Ma & Wang, 2015).

This interaction affects stress redistribution, displacement patterns, and strain development, potentially exceeding the limits anticipated in design provisions (Torres et al., 2021). Furthermore, the elastic modulus of concrete decreases over time, further modifying the structure's dynamic properties (Ma et al., 2016). Additionally, various damage mechanisms may reduce the effective cross-sectional area of the silo walls, exacerbating their structural vulnerability (Xiong et al., 2022).

Amid these complexities, the present study aims to perform a comprehensive numerical analysis of the interaction between creep and seismic loading in large reinforced concrete silos operating at elevated temperatures. The objective is to enhance understanding of their long-term structural behavior and to provide insight that supports the development of safer and more resilient design strategies.

Theoretical Framework or Literature Review

Literature Review

Silos in Mexico

The design and construction of large-scale reinforced concrete silos has long been a necessity in Mexico due to their versatility in supporting complex industrial processes. However, their design was historically constrained by the absence of specific national guidelines. It was not until 1969 that the Comisión Federal de Electricidad introduced the first Manual de Diseño de Obras Civiles, which incorporated procedures for analyzing and designing non-conventional structures across different regions of the country (Hernández, 2021). Although this manual has undergone continuous revisions and modifications, the procedures it outlines remain limited to basic structural analyses, lacking the tools necessary to capture nonlinear behavior or time-dependent effects (Ordaz & Meli, 2004).

This limitation reflects a broader issue, the predominantly empirical nature of silo design in Mexico. While adequate for basic performance requirements, these methods may overlook critical behaviors such as creep interacting with dynamic loads, especially in high-temperature environments or seismic zones. The gap between design practice and advanced structural modeling highlights the need for updated methodologies that can more accurately assess the long-term performance of these structures.

Creep in reinforced concrete silos

One of the most critical effects of creep in silos is the progressive increase in deformations, which alters the original distribution of stresses within the structure (Kawecki et al., 2022). This redistribution can lead to stress concentrations in vulnerable areas, particularly in the silo walls, where the combined influence of mechanical and thermal loads promotes the development of cracking, (Breslavsky & Chuprynin, 2021). These cracks not only reduce the structural capacity of the material but also serve as initiation points for localized failures that can propagate rapidly and compromise the global integrity of the structure (Modi et al., 2024). When combined with dynamic loads, such as seismic events, the degradation process is accelerated, raising serious concerns regarding structural safety and service life.

Despite the recognized importance of creep, existing studies often treat it as a secondary effect or analyze it in isolation from dynamic actions. For example, while Liu, Zhou, Zhang and Jiang (2021) directly link creep-induced deterioration to several structural failures, their work does not account for interactions with other unfavourable factors. Similarly, although current codes provide basic creep considerations, they fail to address its interaction with cyclic loads or the role of environmental factors such as temperature variations and humidity (Yu et al., 2022).

The current state of literature reveals the lack of comprehensive models that accurately capture the long-term behavior of creep under complex loading scenarios and specific environmental conditions (Reddy et al., 2023). Addressing this shortcoming is essential to ensuring structural resilience. Therefore, this study aims to address this gap by examining the complex effects of creep in reinforced concrete silos, an area still underexplored, through advanced numerical models and robust analytical methodologies that enhance the durability and reliability of these nonconventional structures.

Relationship between creep and dynamic loads

Creep, traditionally understood as the slow, time-dependent deformation of materials under constant load, plays a more complex and critical role in dynamic systems, particularly under seismic loading. Hetland & Simons (2010) observed that post-seismic creep rates are influenced not only by time but also by the discrepancy between the total slip expected during a seismic cycle and the sum of coseismic slip and transient post-seismic creep. This finding suggests that conventional models may fail to fully capture the nuances of fault behavior under seismic stress. Moreover, while typical post-seismic creep exhibits an initial peak followed by decay, certain frictional faults present delayed post-seismic creep, where rates initially remain low, then increase, and eventually fall below the plate convergence rate, highlighting the need for more adaptable modeling approaches.

Ma et al. (2016) examined the effects of sustained versus instantaneous loads and demonstrated that creep alters the mechanical properties of concrete over time, thereby affecting both static and dynamic responses. Their numerical analysis of an arch bridge showed that natural frequencies increase progressively over time due to creep effects. However, although their study underscores the importance of considering creep in dynamic analyses, it is limited to bridge structures. Similarly, Ma & Wang (2015) emphasized that neglecting long-term effects in seismic design can lead to a significant underestimation of structural responses. Yet, their findings are primarily based on analyses of CFST bridges, raising questions about their generalizability to other structural systems.

Despite the growing interest in the dynamic implications of creep, a notable gap remains in the literature concerning reinforced concrete silos. These structures differ substantially from bridges in geometry, loading distribution, and functional demands, and their long-term behavior under the combined influence of creep and seismic loading has not been thoroughly investigated.

Methodology

The study case is a silo with a concentric conical hopper is presented since, in addition to being one of the most popular geometries in recent years, it has been identified as one of the most efficient for storing large quantities of granular materials due to its mass flow that eliminates obstructions possibilities minimizing the material segregation (Picone, 2024). For this case study, the primary creep behaviour is evaluated over a period of 210 days, according to the parameters identified by ASTM International (2018) for the type of concrete used in the silo. Subsequently, a seismic load representative of a high-intensity earthquake is applied, followed by a comparison of the secondary creep development over 20 years with a scenario where dynamic loads are absent. This approach estimates the durability of the structure in both cases, thereby allowing the identification of how dynamic loads influence the development of creep.

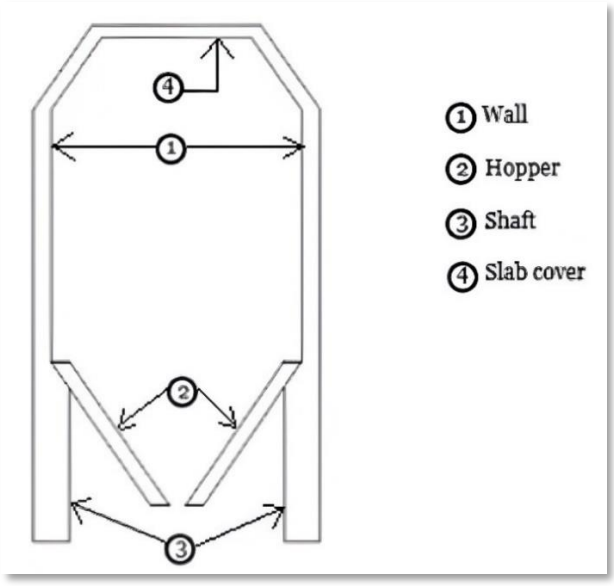

Figure 1. Silo longitudinal section.
Source: By the authors

Table 1.
Silo geometry.

Element	Thickness
Shaft (m)	0.7
Wall (m)	0.35
Hopper (m)	0.35
Superior slab (m)	0.2

Source: By the authors

This study case has 40 m height and 18 m diameter, presenting a height/diameter ratio of 2.22. The concentric conical hopper is 5 m height, presenting a discharge opening in its lower part with a 2.25 m diameter.

Table 2.
Reinforced steel arrangement in the wall.

Depth (m)	Group	Longitudinal arrangement	Transverse arrangement
1-8	1	2 No. 5 links 15 cm	2 No. 4 links 20 cm
9-11	2	2 No. 6 links 15 cm	3 No. 4 links 20 cm
12-22	3	2 No. 8 links 15 cm	4 No. 4 links 20 cm
23-30	4	2 No. 8 + 2 No. 3 links 15 cm	5 No. 4 links 20 cm

Source: By the authors

Materials

Study cases proposed were carried out considering concrete at 28 days age with the mechanical properties shown in table 3.

Table 3.
Concrete mechanical properties.

Concrete properties	
Density (kg/m^3)	2400
Elastic modulus (Mpa)	22974
Poisson´s ratio	0.3
Coefficient of thermal expansion (c^{-1})	9.90E-06
Bulk modulus (Pa)	1.91E+10
Shear modulus (Pa)	8.84E+09

Source: By the authors

Table 4.
Concrete mix used.

Concrete dosage	
Cement (kg/m3)	315
Finne aggregate (kg/m3)	46
Quartz aggregate (kg/m3)	1003
Water (kg/m3)	180

Source: Bouziadi, Boulekbache, Haddi, Hamrat, & Djelal, 2020

Grade 42 steel is used to reinforce the elements that make up the structural components of reinforced concrete silos. It meets the following parameters:

Table 5.
Reinforcing steel mechanical properties.

Steel properties	
Density (kg/m3)	7850
Elastic modulus (Mpa)	200000
Bulk modulus (Pa)	1.67E+11
Shear modulus (Pa)	7.69E+10
Coefficient of thermal expansion (c-1)	1.17E-05
Tensile strength (Pa)	4.20E+08
Compressive strength (Pa)	6.20E+08

Source: By the authors

Creep behaviour laws

Numerical analysis of concrete creep is performed based on the two main implicit behaviour laws. The time hardening law has been shown to have great results in estimating primary creep at small periods of time. For the concrete used in these study models, it is known that primary creep phase ends after a period of 210 days (Bouziadi et al., 2020).

$$\dot{\varepsilon}_{cr}=C_1\sigma^{C_2}t^{C_3}e^{-C_4/T} \qquad (1)$$

Where: C1, C2, C3, C4 – material constants, t – time, T – temperature, σ – stress

For a longer study time, Norton's law is capable to study the creep effects for long periods of time, evaluating the secondary phase.

$$\dot{\varepsilon}_{cr}=C_5\sigma^{C_6}e^{-C_7/T} \qquad (2)$$

Where: C5, C6, C7 – material constants, T – temperature, σ – stress

Stored Material Properties

Stored material properties, such as the density, the angle of friction and the coefficient of friction, are considered according to the established parameters in the North American regulations, presenting the following magnitude (American Concrete Institute, 2016).

Table 6.
Stored materials properties.

Property	Value
Density, γ (kg/m3)	1410
Angle of internal friction, φ	33
Effective angle of internal friction, δ	44 to 52
Coefficient of friction against concrete, μ´	0.6

Source: American Concrete Institute, 2016

Static loads

One of the most accurate and used ways to estimate static load conditions that the material will exert of the silo is through the Janssen method, which is based on the study of horizontal equilibrium layer of stored material this method is recommended by American Concrete Institute (2016). In this way the vertical loads at a depth Y are given by equation 3.

$$q=\frac{\gamma R_H}{\mu'(1-\text{sen}\Phi)}\left[1-e^{-\mu'(1-\text{sen}\Phi)\,Y/R_H}\right] \qquad (3)$$

Where: Rh – hydraulic radius, Y – depth, γ – density, φ – angle of internal friction, μ´ – coefficient of friction against concrete.

The horizontal pressures known as ring stress for the case of silos of circular rein-forced concrete are calculated as:

$$p=1.36\ D\ q(1-\text{sen}\Phi) \qquad (4)$$

Where: D – silo diameter

Vertical friction per unit length is obtained from equation 5.

$$V=R_H(\gamma Y-q) \qquad (5)$$

Based on the three mathematical expressions raised above, expressions are determined to obtain the existing loads in the silo hopper. Vertical pressure in this element is given by:

$$q_y=q_0+\gamma h_y \quad (6)$$

Where: q0 – silo diameter, hy – hopper depth

Normal pressure to the surface will be considered as the most unfavourable of equations 7 and 8.

$$p_n = \frac{q_y \tan\theta}{\tan\theta+\tan\varphi'} \quad (7)$$

$$p_n=q_y[\sin^2\theta+(1-\text{sen}\Phi)\cos^2\theta] \quad (8)$$

According to the expression used to calculate the normal pressure, it will be defined the calculation of the friction forces and will be chosen in a manner consistent with previous expressions.

$$v_n= p_n \tan\Phi' \quad (9)$$

$$v_n= q_y \,\text{sen}\Phi\, \text{sen}\,\theta\, \cos\theta \quad (10)$$

Dynamic loads

Every civil structure is subjected to various earthquake effects during its working life. Creep influence on dynamic behaviour due to seismic loadings is mainly originated by structural displacements, internal stresses and material properties which vary with time (Hetland & Simons, 2010). For this case, structural configuration silo presents an initial condition in which 210 days concrete primary creep is considered as initial condition for the successive time-history transient analysis. This numerical analysis is followed by a secondary creep study for 20 years and the results are compared between this case and the other one that no presents seismic loadings to verify how the earthquake presence affects the creep development. In this numerical model, cement mass vibrates convectively during seismic excitation and is connected to the impulsive mass to the silo wall, (Compagnoni et al., 2012). So, the general motion equation which solves the transient structural equilibrium is:

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K(t)]\{x\} = -[M]\{r\}\{\dot{u_g}\} \quad (11)$$

Where: [M] – mass matrix, [C] – damping matrix, {x} – displacement vector, {r}– unit influence vector, {üg}–ground acceleration, [K(t)]–stiffness matrix.

This silo case is placed in La Venta, in Mexico (16.4511 N, 98.7764 W), as is shown in figure 2. The soil is of granitic gneiss type, (Lázares, 2003). This corresponds to hard soil conditions Therefore, soil-structure interaction effects are neglected (Comisión Federal de Electricidad, 2015). An embedded support condition is assumed to represent the transfer of stresses to the foundation. The seismic design acceleration signal is obtained with the PRODISIS program, a program that was created and given by the Comisión Federal de Electricidad, 2015, in Mexico. The signal is obtained with a history time series in which the response spectrum matches the design spectrum. Figure 4 shows the synthetic used signal and is analysed in its frequency content through Short Fourier Transform (SFT).

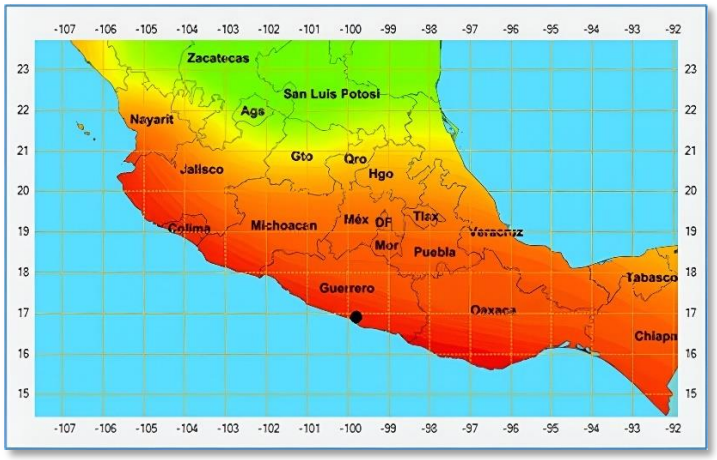

Figure 2. Seismic zone. La venta, Guerrero, México.
Source: Prodisis, Comisión Federal de Electricidad, 2015

The synthetic seismic signal generation process implemented in PRODISIS (Comisión Federal de Electricidad, 2015) employs stochastic signal techniques based on spectral and modal models (Clough & Penzien, 1993). The procedure begins with spectral modeling using a target design response spectrum obtained from the Federal Electricity Commission (CFE) seismic design guidelines. A signal is then constructed to match the specified frequency content of this target spectrum. Signal generation is performed through envelope modulation combined with random phase variables. The synthetic acceleration time history, a (t), is expressed as:

$$a(t) = H(t)\sum_{i=1}^{N}\cos(\omega_i t + \phi_i)\sqrt{2S(\omega_i)\Delta\omega} \qquad (12)$$

Where: *H(t)* is a trapezoidal-type function with exponential decay, simulating the energy buildup and decay of real earthquakes, ϕ_i is a random phase variable uniformly distributed, and $S(\omega_i)$ is the target power spectral density (based on the desired response spectrum).

The generated signal is iteratively refined until its response spectrum closely matches the target design spectrum within a predefined tolerance.

The software internally, utilizes the following parameters: a seed signal recorded at the site, the target design spectrum corresponding to a specified return period, the total duration of the signal, the time step (Δt), frequency values and frequency range, both of which are defined based on the total duration and time step, and randomness in phase.

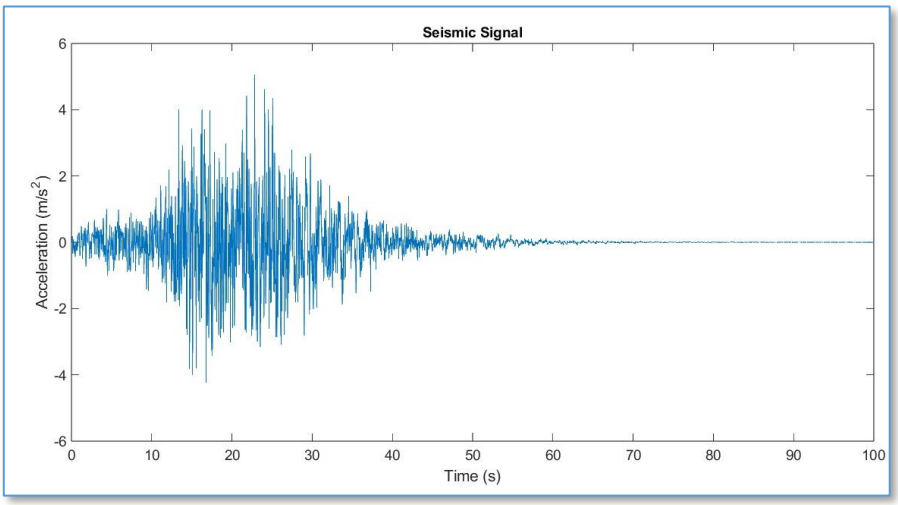

Figure 3. Applied synthetic signal.
Source: By the authors

The validation process consists of two stages. First, spectral match validation is performed by generating a family of synthetic earthquake records and comparing the average of their response spectra with that of the seed record. This comparison is typically required to achieve agreement within 10% (Comisión Federal de Electricidad, 2015; Vargas Colorado et al., 2022). Second, structural response validation is conducted by comparing the time-history responses of structural models subjected to both real and synthetic earthquakes. This step aims to verify statistical equivalence in key response parameters, such as peak displacement, peak acceleration, and energy demand (Guzmán Ventura et al., 2020; Vargas Colorado et al., 2022).

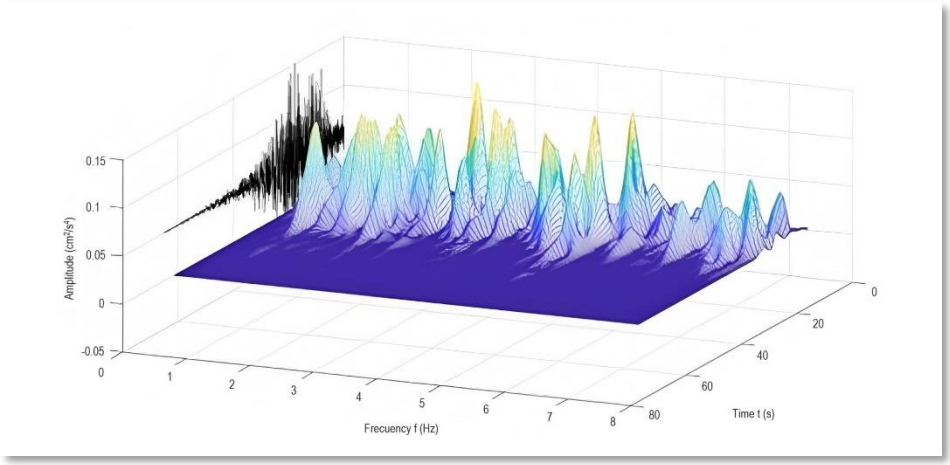

Figure 4. Short Fourier Transform of the seismic signal.
Source: By the authors

A Hamming window was used to obtain the SFT, the obtained surface was normalized to have the same energy that the signal has. When the silo is full, the fundamental period is T= 0.45 s, and its corresponding frequency is depicted with the frequency content of the signal given by its Fourier transform norm in figure 5. It is evident, that the seismic signal is going to demand the silo structure in an important matter.

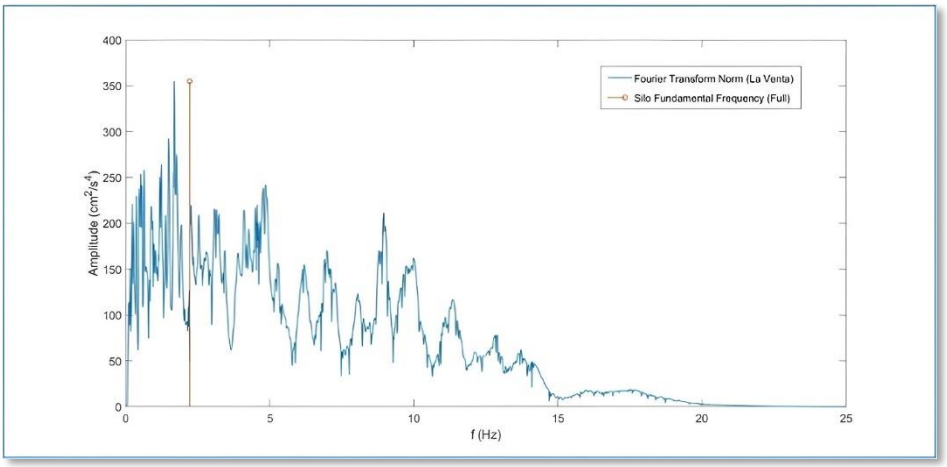

Figure 5. Silo frequency on the frequency content of the signal.
Source: By the authors

Results and Discussion

Numerical analysis is carried out with the finite element method, using Solid 186 element for concrete, a three-dimensional, higher-order solid element that excels at capturing complex stress and deformation patterns in continuum structures, supports geometric nonlinearity, and accommodates a wide range of advanced material models, including creep and temperature-dependent behaviors. Reinforcing steel is represented by Link 180 element types, a three-dimensional spar element transmits only axial forces

between its nodes and supports geometric nonlinearity to accurately capture large strains. It also accommodates advanced material models, including creep and temperature-dependent behavior.

These materials interact in a contact surface between them, making the mesh nodes coincide. Mesh is crafted for an optimized element size resulting in 7614 nodes and 1033 elements. For the application of the existing loads on the structures, each one was discretized in sections of 1 m height, to apply the loads calculated according to the expressions presented in section 2. A perfect embedment in the lower face of the shaft is considered to simulate the behaviour that the superstructure would have when it is linked to its respective foundation. Likewise, the study period is defined considering that the primary creep stage will take place within the first 210 days of analysis and its behaviour will be studied with Time Hardening law. For numerical study purposes, the primary stage is subdivided into 211 parts where the first of them will have one second duration and the linear-elastic case will be presented. The remaining 210 steps are equidistantly distributed in the time analysis and with the obtained results of these steps, various curves are plotted to understand how the creep phenomenon has behaved in these cases. Secondary creep will appear after seismic excitation and its development continues for the next 20 years.

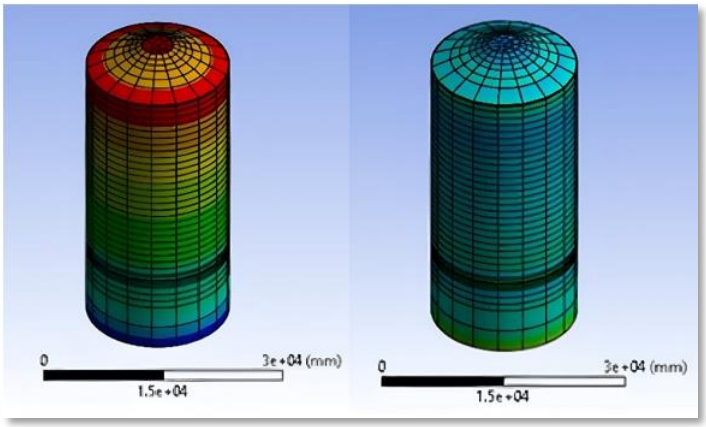

Figure 6. Total displacement at primary stage (left) and maximum principal strain at secondary stage (right).
Source: By the authors

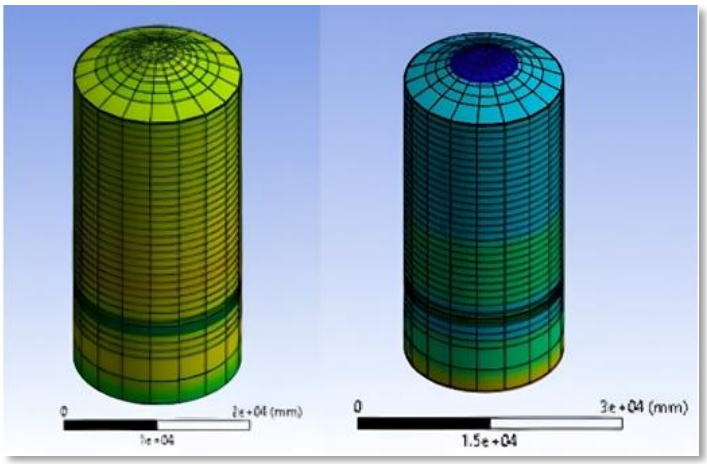

Figure 7. Middle principal strain and Equivalent creep strain at secondary stage.
Source: By the authors

Numerical analysis

Through the information treatment from the output files, it has been possible to identify the areas with the greatest unfavourable creep effects. These elements are located mainly in the wall, the hopper, and the shaft.

Table 7.
Most unfavourable elements ubication.

Element	Ubication	Coordinates (m)		
		x	y	z
717	Shaft	1.5508	6.5274	8.7065
161	Hooper	1.5603	10.881	8.6618
197	Wall	1.5621	11.55	8.6553
593	Wall	1.6427	33.604	8.4438
44	Slab	1.1637	38.337	5.5706
853	Hooper	0.90238	7.769	4.9799

Source: By the authors

Primary Creep Results

The best way to know the primary creep effects is studying the equivalent creep strain in the main elements of the silo. It is possible to identify how the elements present rapidly deformations that decreases with time. Primary creep strain results after 210 days are presented below.

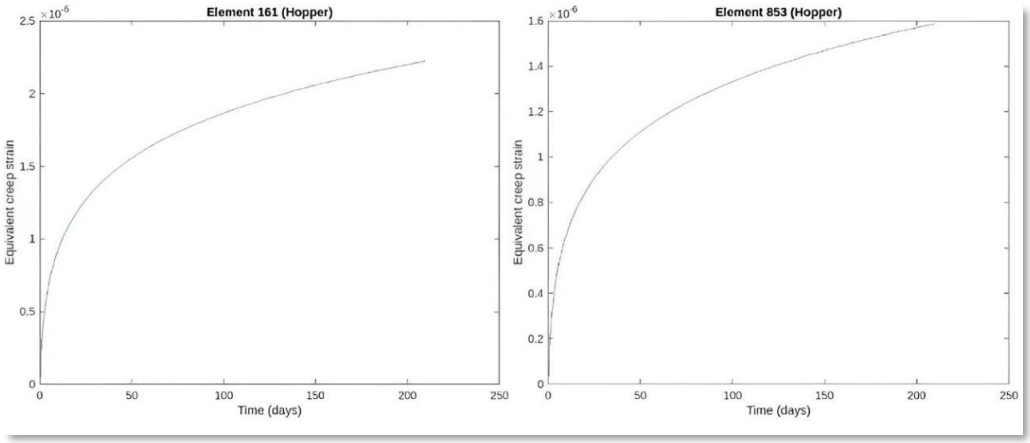

Figure 8. Equivalent primary creep strain in the hopper.
Source: By the authors

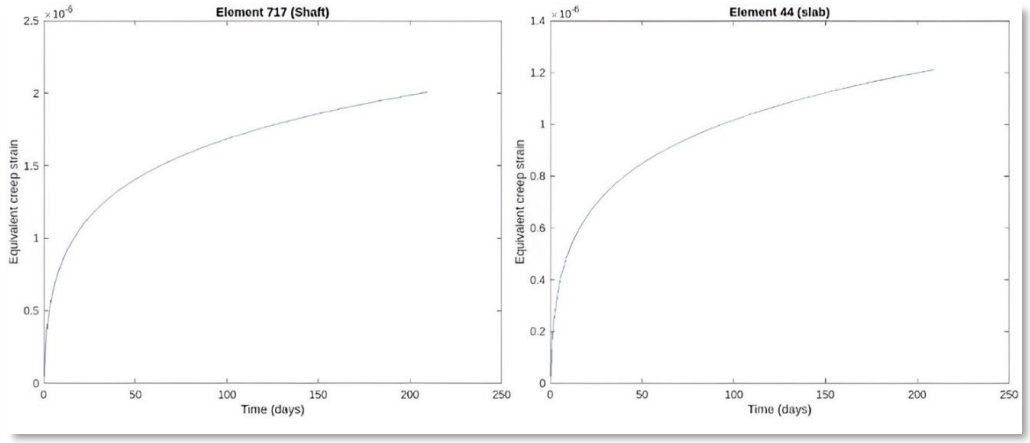

Figure 9. Equivalent primary creep strain in the shaft and the slab.
Source: By the authors

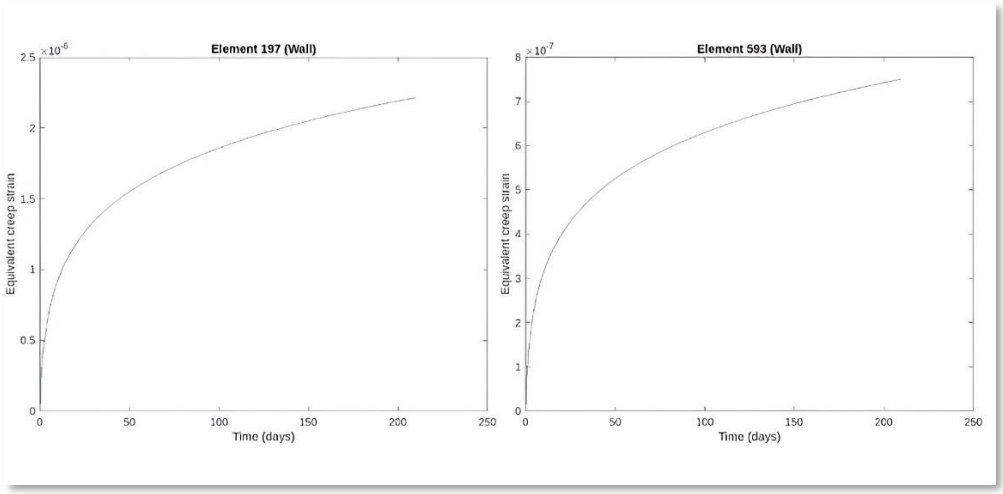

Figure 10. Equivalent primary creep strain in the wall.
Source: By the authors

Time-history analysis results

Seismic signal is applied in z direction after 210 days since the creep started. The numerical results show how the silo presents permanent deformation after the application of the accidental loads. The solution for the transient analysis is presented for the critical nodes.

Table 8.
Time-history analysis for critical nodes.

Element	#node	x(m)	y(m)	z(m)
Superior slab	366	4.76	38.5	-27.5
Wall	1200	5.78	12	6.89
Shaft	5315	5.78	1.5	6.89
Hopper	6090	5.51	8	0.97

Source: By the authors

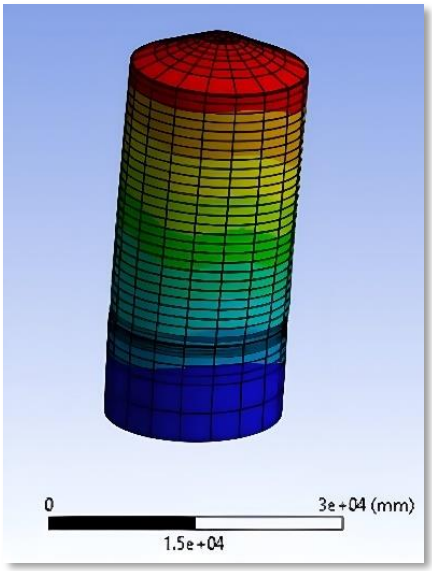

Figure 11. Permanent displacement after seismic load.
Source: By the authors

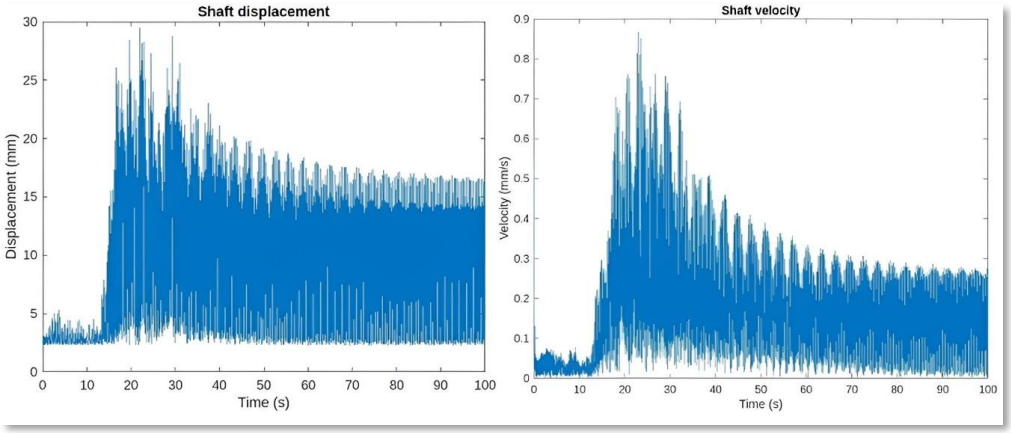

Figure 12. Dynamic response in the shaft.
Source: By the authors

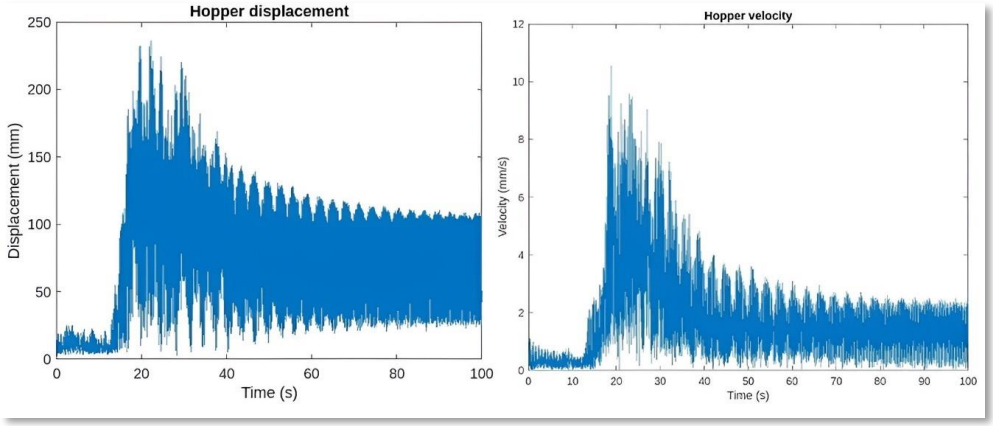

Figure 13. Dynamic response in the hopper.
Source: By the authors

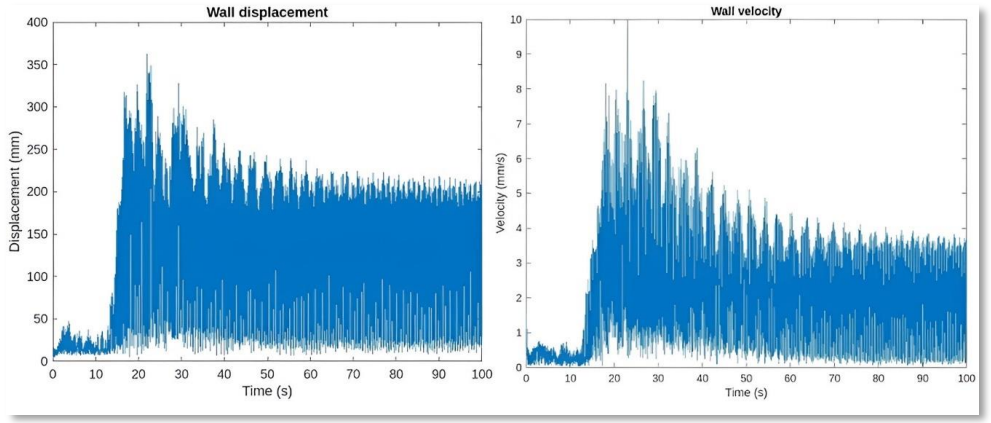

Figure 14. Dynamic response in the wall.
Source: By the authors

Secondary Creep results and comparison

For this stage analysis a comparison is presented where the first case is secondary creep after the seismic excitation, the second one is a stationary stage after primary creep, no seismic load is considered in this case. For both sceneries the analysis is done for 20 years, and the most relevant differences are presented below.

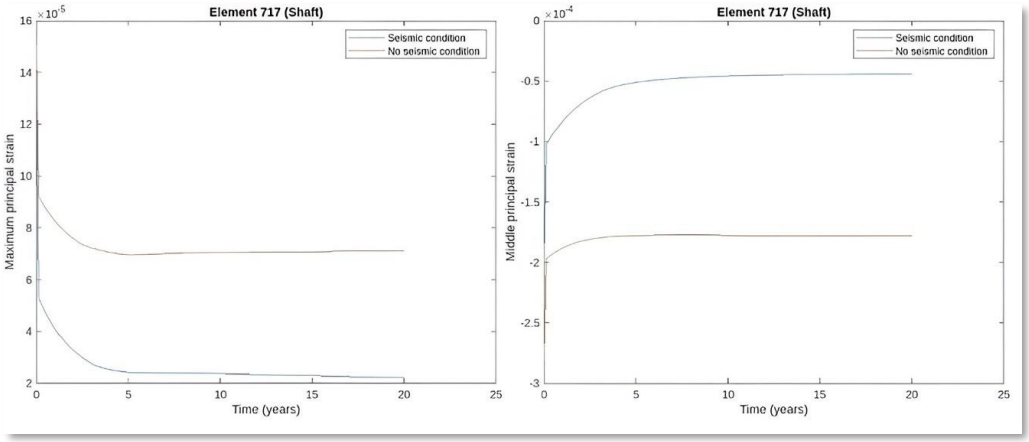

Figure 15. Secondary stage comparison in the shaft.
Source: By the authors

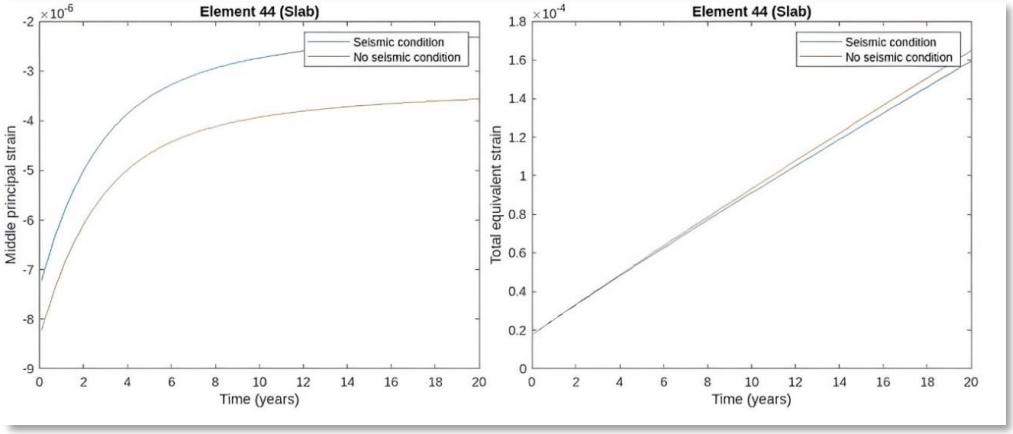

Figure 16. Secondary stage comparison in the slab.
Source: By the authors

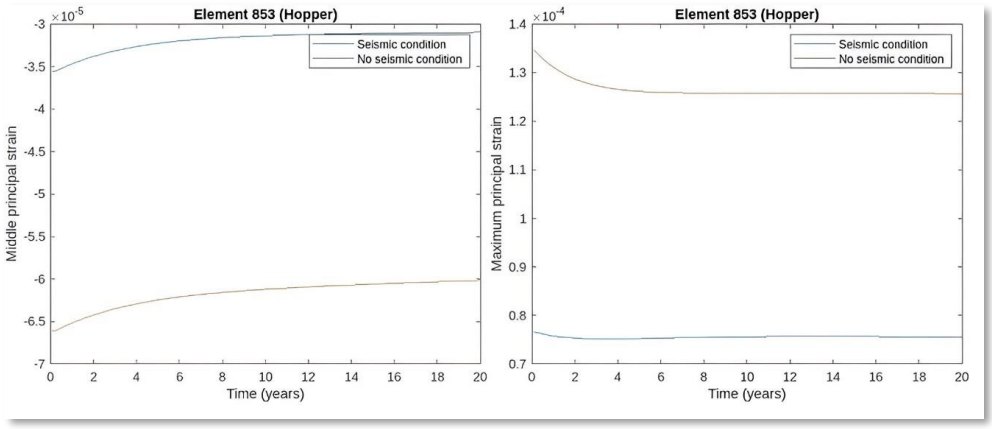

Figure 17. Secondary stage comparison in the hopper.
Source: By the authors

Influence of creep on natural frequencies

The calculation of the natural frequencies in the case study is carried out by considering the degradation of the modulus of elasticity over time, as well as the structural configuration for each of the proposed scenarios. It is demonstrated that the frequencies of the vibration modes increase, with a greater difference observed in the higher modes. It has been established that reinforced concrete silos exhibit vibration modes

within a narrow frequency range; therefore, the error induced by disregarding the effects of creep could exceed the difference between two closely spaced frequencies.

Table 9.
Natural Frequencies for presented creep scenarios.

	Natural Frequencies (Hz)		
Mode	Primary Creep	Secondary Creep	Secondary Creep after Earthquake
1	2.21	2.4296	2.4196
2	2.21	2.4296	2.423
3	3.5185	3.3387	3.3301
4	3.5185	3.3387	3.3308
5	3.9035	3.721	3.7074
6	3.9036	3.721	3.7164

Source: By the authors

After 20 years of creep the frequencies rise 9.94%, 5.11%, 4.68% at modes 1,3 and 5 respectively. Secondary creep and secondary creep after earthquake rise 0.41% and 0.12%.

Conclusions

This study demonstrates that creep deformations significantly alter the stress distribution in reinforced concrete silos, with pronounced effects in the hopper, shaft, and wall. During the primary creep stage, numerical results show a slight increase in principal strains, accompanied by a degradation of the elastic modulus, which modifies the initial conditions for subsequent analyses. Although the level of deformation at this stage may appear similar to that predicted by linear-elastic analysis, its long-term implications become increasingly relevant, highlighting the importance of incorporating time-dependent material behavior in the design of durable structures.

The time-history analysis reveals that seismic loading induces permanent deformations and changes the state of stress from compression to tension in critical regions near the top of the shaft, increasing the likelihood of cracking, particularly in the shaft and hopper. Significant damage is expected in primary structural members, with possible failures in secondary elements. The wall undergoes the largest displacements in its lower third, while stress redistributions are concentrated in the hopper and shaft. These results reflect a critical scenario, as conventional seismic design manuals typically do not account for nonlinear behavior of large silos at this stage of service life.

Secondary creep further amplifies deformations, especially in the upper shaft and hopper, where displacements in the -y direction become significant. The progressive increase in ring stresses and mid-height principal strains evidences the continued deterioration of structural integrity. Compared to the non-seismic case, seismic excitation results in significantly greater long-term deformations due to the contribution of instantaneous loading. These findings suggest that seismic actions accelerate the progression of creep, potentially leading to earlier onset of critical damage and stability issues.

The combined effects of creep and seismic loading contribute to a progressive loss of stiffness, altering the dynamic response of the structure. Natural frequency analysis confirms that permanent seismic deformations disrupt the silo's axisymmetry, resulting in irregular vibration modes. This change in dynamic behavior may also imply the emergence of soil-structure interaction effects that are not captured by traditional linear-elastic analyses. Secondary creep is expected to continue altering the natural frequencies, exacerbating these issues over time.

Overall, this study underscores the necessity of explicitly considering both creep and seismic effects in the analysis and design of reinforced concrete silos. Neglecting these phenomena may lead to underestimated demands, reduced structural reliability, and increased risk of failure. Given the geometric and mechanical complexity of large silos in seismic zones and the current lack of design standards that adequately address these challenges there is a clear need for further research into the interaction between time-dependent concrete behavior and dynamic loads. Additionally, future work should include probabilistic reliability analyses to support the development of optimal design strategies for these critical structures.

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Sistema de inteligencia artificial basado en manejador de reglas dinámico, operado sobre base de datos

Artificial intelligence system based on a dynamic rule-based engine operated on a database

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Resumen

Se presenta una propuesta desarrollo de un manejador de reglas, aplicable a sistemas de filtrado, de diagnóstico o para toma de decisiones, esta propuesta permite el manejo de reglas sencillas o compuestas, tanto que incluyan: Operaciones de consultas a bases de datos, operaciones aritméticas y operadores relacionales, acepta reglas conjuntivas y disyuntivas, se crea un pequeño lenguaje para representar reglas, mismas que son almacenadas en base de datos y por tanto pueden crecer dinámicamente. El manejador se utiliza como herramienta para otros desarrollos que requieran esta funcionalidad, el producto final es una librería en lenguaje PHP.

Palabras clave: Manejador de reglas, inteligencia artificial, bases de datos.

Abstract

We present a proposal for the development of a rule handler, applicable to filtering, diagnostic, or decision-making systems. This proposal allows the management of simple or complex rules, including: database query operations, arithmetic operations, and relational operators. It accepts conjunctive and disjunctive rules. A small language is created to represent rules, which are stored in a database and can therefore grow dynamically. The handler is used as a tool for other developments that require this functionality, and the final product is a library in PHP.

Keywords: rule handler, artificial intelligence, database.

Introducción

Dado el incremento del uso de la inteligencia artificial en la actualidad, la representación y manejo del conocimiento ha tomado más importancia, una técnica para manejo de conocimiento son los sistemas basados en reglas con sus variantes (Hou et al., 2025), así como la inteligencia artificial explicable (Tchuente et al., 2024), que permiten que el proceso y salida de la inteligencia artificial sea más comprensible para los humanos.

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Los sistemas basados en árboles de decisión operados a través de manejadores de reglas pueden manejar diferentes tareas como: Clasificación (Pawuś e al., 2025), (Zolfagharnasab et al., 2025), filtraje de datos o información, hacer diagnósticos (Aguilera-Venegas et al., 2023), así como otras tareas con base en un conjunto de reglas fijas definidas por el usuario y dependiendo de la capacidad del sistema computacional inteligente puede o no actualizar dichas reglas para poder resolver nuevas situaciones. De igual forma se observa que el almacenamiento de las reglas en las bases de datos es una buena opción (Martinez Llario et al., 2017).

El propósito de este artículo es mostrar el diseño de un sistema manejador de reglas, este diseño tiene características funcionales, por ejemplo, permite separar las reglas de conocimiento respecto del código fuente, esta separación permite la operación del conocimiento de forma dinámica lo que permite: Agregar, modificar, borrar y explorar reglas con el sistema en operación. Las reglas de conocimiento son almacenadas en una tabla en una base de datos. Otra cualidad de este manejador de reglas es la posibilidad de incluir reglas con acceso a base de datos, con los permisos necesarios. Lo que amplia el uso en la toma de decisiones sobre bases de datos ya operativas y que son alimentadas por otros sistemas.

Este documento viene organizado y se comienza al presentar trabajos similares, posteriormente el marco teórico que proporciona elementos importantes para la mejor comprensión del artículo, posterior a ello se presenta nuestra propuesta, luego los resultados obtenidos, finalmente las conclusiones y las referencias.

Marco teórico y Revisión de literatura

Los sistemas basados en reglas constan de un intérprete y reglas, esto también se puede interpretar de la siguiente forma:

- Motor de inferencia.
- Base de conocimientos.

Motor de inferencia

El papel de interpretar, seleccionar y aplicar reglas es atendido por el motor de inferencia. Mediante inferencia es posible seleccionar el conjunto de reglas que coinciden en el contexto, en este proceso se debe hacer coincidir reglas y resolver resolución de conflictos.

Los motores de inferencia pueden ser de tres tipos:

- Basados en reglas.
- Basados en lógica difusa.
- Basados en reglas Bayesianas.

Base de conocimientos

Se puede decir que una base de conocimientos contiene reglas y hechos, las reglas pueden ser complejas y los hechos pueden incluir: Secuencias, entidades estructuradas, atributos tales como entidades y relaciones entre ellos. Los hechos son fijos y las reglas incluyen variables. Esta información es declarativa, además puede ser interpretada como la unión de dos componentes fundamentales (Santander - Open Academy, 2023)

- Conjunto constituido por hechos o conceptos pertenecientes a un área específica del conocimiento.
- Conjunto de relaciones entre los hechos y conceptos.

Las reglas modelan instancias, casos o hechos, estas instancias pueden ser almacenadas, junto con sus soluciones asociadas como tuplas en una base de datos relacional. Justo con esta propuesta se apoya la idea de almacenar las reglas en una base de datos relacional.

Las reglas se constituyen como una representación del conocimiento en forma de instrucción condicional. Cada una de las reglas se construye de variables de la base de hechos, así como instrucciones de control (if then else), de igual forma pueden incluir operadores AND y OR (Font Fernández, 2008).

Metareglas

Son reglas que no tienen conexión directa con conocimiento de la aplicación, pero sí de cómo debe aplicarse el conocimiento. Estas son reglas de reglas o reglas del conocimiento. Están directamente relacionadas con los conflictos múltiples y objetivos no acordes, son útiles en resolución de conflictos o bien para dictar el funcionamiento por parte del motor de inferencia para cierto árbol de conocimientos. En este diseño las metareglas pueden indicar que secciones del conocimiento pueden o no se borradas o podadas, también puede definirse una o más metareglas para indicar que debe considerar diferentes líneas del tiempo para ciertas reglas o que no considere el tiempo.

Resolución de conflictos

Ocasionalmente pueden existir más de una regla que se puede aplicar, dado que cumple los requisitos para ser ejecutadas y es entonces cuando surge un conflicto el cual debe de resolverse de una u otra forma. Para resolver dichos conflictos existen diversos métodos como el uso de: metareglas, prioridades o preferencias del usuario.

Desarrollos similares

Algunos desarrollos que usan sistemas basados en reglas son: Clips, Jess, JBoss Rules, y Soar.

En el caso de CLIPS son las iniciales en inglés de: C Language Integrated Production System (Lyndon Johnson Space Center (NASA), 2025) (Sistema de Producción Integrado en Lenguaje C), mismo que aporta los paradigmas de programación imperativa y orientada a objetos, esto permite combinar reglas con objetos. Facilita el control de la secuencia de reglas que se ejecutan. Actualmente es de dominio público.

El Jess es derivado de clips, está constituido por un motor de reglas y un ambiente de programación. Desarrollado por Ernest Friedman en los laboratorios Nacionales Sandia, ubicados en Livermore, California. (Janes & Garcia, 2025). Se puede conectar a aplicaciones desarrolladas en Java, a través de un motor de inferencia por medio de expresiones. Para su evaluación utiliza reglas declarativas para trabajar razonamiento, usa la lista de hechos conocidos y un conjunto de reglas que tratan de coincidir con estos hechos en su base de hechos. Incluyen consultas de memoria de trabajo, así como el encadenamiento hacia atrás. Soporte al estándar JSR-94. Usa una variante del algoritmo de Rete para procesar reglas.

El JBoss Rules es software libre escrito en Java, el Drools (o JBoss Rules) (Proctor et al., 2025) es una solución que se enfoca en la operación de reglas de negocios con un motor de reglas de producción orientada a objetos con encadenamiento hacia adelante (forward chaining), usa el algoritmo Rete, consiste en nodos interconectados con diversas características, analizan entradas transmitiendo los resultados al próximo nodo en caso de coincidir. Usa el JSR-94 en motor de reglas de negocio, aplicación o servicio. Usa JCR (JackRabbit) para administrar las reglas, usa JAAS para autorizar el acceso.

El SOAR es un desarrollo computacional para construir sistemas que se tengan que tomar decisiones, fue elaborado en la Universidad de Michigan (Laird, 2025), Ayuda en tareas a través de un agente inteligente como es el caso de: Problemas abiertos o cerrados. Así como para representar conocimientos en su forma procedural, declarativo o episódico, en las que se busque una aproximación de la verdad. Presenta un ambiente integrado de trabajo para todas las tareas.

Metodología

Esta propuesta de manejador de reglas tiene antecedentes de desarrollo la tesis doctoral (Ramirez Romero, 2013), aquí se presenta el avance y mejoras, también se considera la propuesta de Wang y Yang (Wang et al., 2016). Primero se presenta un análisis de la plataforma computacional, posteriormente en la sección de resultados se formaliza con las definiciones a usar más adelante, luego se presenta la implantación y finalmente un ejemplo de regla compuesta.

Análisis de la plataforma a usar

La plataforma computacional es aquella que indica los programas o software necesarios para la operación de un programa o aplicación. La propuesta se presenta en la ilustración 1.

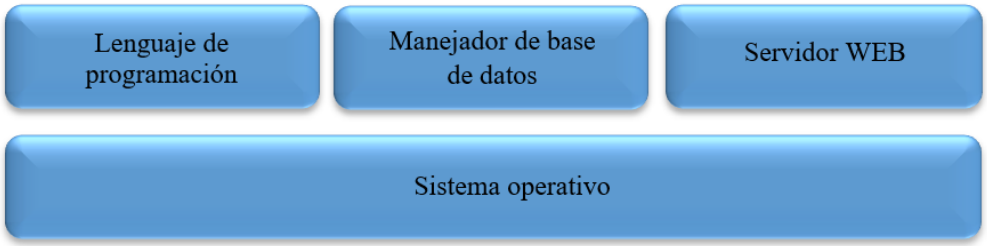

Ilustración 1. Diagrama a bloques de la plataforma necesaria.
Fuente: Elaboración propia.

El sistema operativo sugerido es Linux, con la distribución de fedora core, dada su robustez, ser GNU libre y tiene un manejo adecuado de los recursos. Respecto al manejador de bases de datos la propuesta es MySQL (Smirnova & Tezuysal, 2022), (Grippa & Kuzmichev, 2021), (Widenius et al., 2025) dado que es libre, su desempeño, y su amplia difusión, o bien MariaDB (Widenius, 2025), (Aspin, 2022).

La propuesta de lenguaje de programación es PHP (Lerdof et al., 2025), Se caracteriza por ser rápido en su ejecución.

El servidor de WEB propuesto es HTTPD o Apache httpd server (Behlendorf et al., 2025), es ampliamente usado a nivel mundial en servidores y es (GNU), es configurable, eficiente y corre sobre diferentes plataformas.

El fedora permite trabajar con MySQL + Apache + PHP. O se puede usar: MAMP ó WAMP, que facilita trabajar la propuesta.

Ahora se procede a mostrar en un diagrama a bloques en la ilustración 2, el entorno de funcionamiento de sistema propuesto:

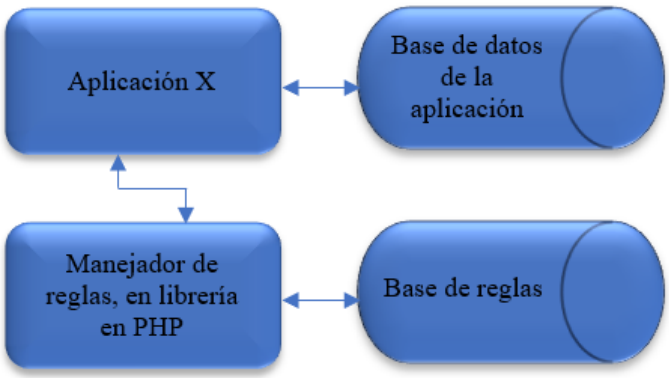

Ilustración 2. Esquema general de entorno.
Fuente: Elaboración propia

En la ilustración 2, se aprecia Aplicación X, que ejemplifica alguna aplicación escrita en PHP, que pueda incluir la librería que contiene el manejador de reglas. Desde la aplicación se incluye el siguiente código:

```
require "reglas_libreria.php";
```

El manejador propuesto almacena las reglas en una base de datos en MySQL, para usar el motor de manejador de bases de datos relacionales y así el esfuerzo puede ser enfocado al desarrollo de mejores algoritmos de búsqueda en árboles que almacenan conocimiento, Se optó por usar el motor MyISAM por su velocidad, con ello se posibilita manejar gran cantidad de reglas sin afectar el tiempo de respuesta.

El sistema propuesto se plantea que se constituya de tres módulos:

- Módulo de carga de reglas a la base de conocimiento.
- Módulo evaluador de reglas.
- Módulo constructor de código SQL a partir de reglas.

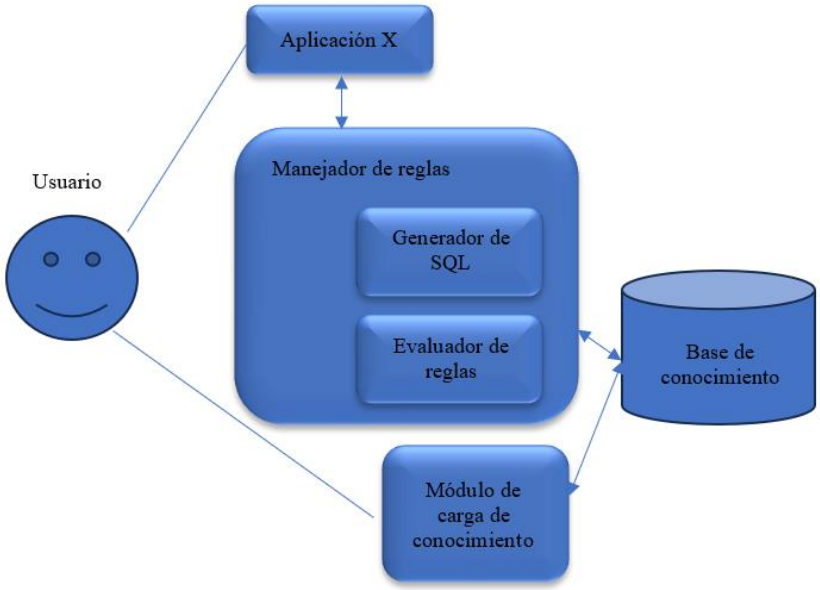

Ilustración 3. Módulos del sistema.
Fuente: Elaboración propia.

Observe la ilustración 3, en el manejador de reglas yace tanto el módulo evaluador de reglas, así como el generador de SQL. El evaluador de reglas esta en permanente uso por cada regla que tenga que ser evaluada, sin embargo, el generador de SQL, solo se activa cuando se evalúa una regla con acceso a base de datos. Por otro lado, observe que el módulo de carga de conocimiento esta fuera de la librería del manejador de reglas, porque este módulo lo que busca es alimentar la base de conocimientos de forma integral y de forma gráfica, sin embargo, se pueden alimentar directamente las reglas a la base de conocimiento.

En este artículo se da énfasis al módulo evaluador o manejador de reglas y aunque los otros módulos (de carga de reglas o ingreso de reglas y constructor de código SQL o traductor reglas a SQL) son parte una parte importante, aquí no se desarrollan.

Resultados y discusión

El producto principal de este trabajo que se mostrará de la siguiente forma: Primero se presentará las definiciones y estructura de datos del árbol de conocimiento, posterior a ello la implantación de la propuesta.

Árbol de conocimientos propuesto.

El manejador de reglas en ocasiones llamado motor de inferencia trabaja directamente con una base de conocimiento, misma que a continuación se define para posteriormente enfocarnos al manejador.

Base de conocimiento

A continuación, se denota la teoría de la Base de Conocimientos (BC en lo sucesivo) y sus componentes.
Definición 1. BC se define formalmente como:

$$BC=Reglas \cup Hechos \cup Func \cup MetaR$$

Donde:

- *Reglas*. Las reglas de la Aplicación X. cuyo resultado es cero o uno, Reglas=f(x)={0,1}
- *Hechos*. Reglas con valores constantes.
- *Func*. Funciones, operaciones aritméticas, o a bases de datos, o algún procedimiento y regresan valores o bien datos.
- *MetaR*. Reglas para el manejo de reglas.

Con base en la definición 1, existen diferentes tipos de elementos, en la tabla 1 se presentan algunos ejemplos.

Tabla 1.
Ejemplos de elementos de una BC

Tipo	Ejemplo
Reglas	fecha_aplic <= fecha_actual
Hechos	dias_maximos = 9
Func	fecha_actual
MetaR	tiempo_max_por_regla = 2ms

Fuente: Elaboración propia.

De la tabla 1, la regla del tipo Reglas, recibe como parámetro fecha_aplic y calcula mediante una función implantada en la misma librería en PHP, de tipo *Func* el valor de la fecha_actual, después compara y en caso de coincidir regresa 1, caso contrario regresa 0.

Para el caso de los del tipo *Hechos*, solo se define el valor que puede tomar un parámetro que a su vez es requerido por alguna regla de tipo Reglas.

Las de tipo *Func*, son funciones o procedimientos disponibles en las funciones básicas dentro de la librería del manejador de reglas, por ejemplo, pueden calcular: Fecha actual, fecha máxima, temperatura del CPU, algún dato recogido de algún puerto, etc.

Finalmente, las del tipo *MetaR*, son reglas que rigen la operación general del manejador de reglas. Observe la tabla 1, dice Tiempo_max_por_regla = 2ms, lo que dice que el tiempo máximo que puede emplear en evaluar una regla es de 2 milisegundos. Pero también se puede usar para emplear cierta resolución de conflictos, prioridades o criterios de preferencia de usuario, o bien que para cierta regla debe evaluar la regla, sus hijos y subir un solo nivel y evaluar reglas asociadas al nivel del padre.

Para representar el conocimiento se propone una estructura de árbol abierta, como se aprecia en la ilustración 3.

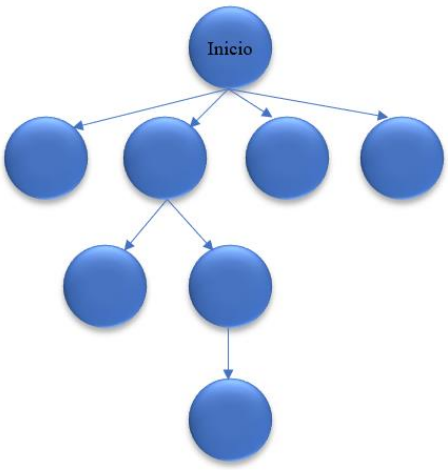

Ilustración 4. Estructura de arbol para representar el conocimiento.
Fuente: Elaboración propia.

De la ilustración 3, se dice que cada círculo representa una unidad de conocimiento y por las relaciones permite darle veracidad para cierto entorno.

En la ilustración 4, se aprecia la forma de interconexión de nodos, la idea se toma de (Ramirez Romero, 2013), esta permite construir un árbol general constituido por: m niveles, así como n nodos, para cada nivel.

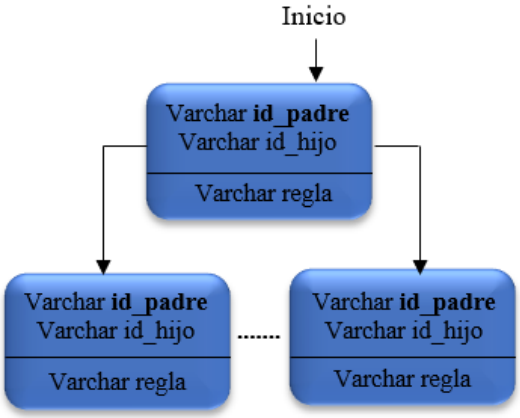

Ilustración 5. Interconexión de nodos.
Fuente: Elaboración propia.

La estructura de datos no lineal de un árbol se traduce en una estructura lineal, pero la estructura lineal puede crecer en cada nodo por un renglón en una base de datos.

Definición 2. Se refine como regla raíz o inicio en lo sucesivo llamada R_{ini} a la primera regla en la estructura de árbol y de la cual se pueden derivar más reglas, R_{ini} => R_1, R_2, …, R_n. y la cual no tiene regla que la anteceda.

$$\forall R_{ini} \mid Padre(R_{ini}) = \{\}$$

Donde: ini representa el inicio.

La definición de la función Padre (R) se da en la definición 3.

Además, solo existe una R_{ini}

En este caso se dice que R_{ini} genera de forma directa a R_1, R_2 y R_n y puede generar hasta n reglas.

Definición 3. Existe una función Padre (R_i) que regresa, generadora de la R_i o también llamada regla antecedente.

R_{ini} => R_i,
Padre (R_i) = R_{ini}

Definición 4. Existe una función Hijo (R_i) que regresa, la(s) regla(s) que se derivan de la regla R_i

R_{ini} => R_i,
R_{ini} => R_k,
Hijo (Rini) = {R_i, …, R_k.}

Definición 5. Se define una BC modelada en una estructura de datos de árbol como: Un conjunto no vacío de expresiones o reglas R_1, R_2, …; R_n de la forma:

$$R_{ini} = \text{Hijo } (R_{ini}) = R_i$$
$$R_{ini} = \text{Hijo } (R_{ini}) = R_j$$
$$R_k = \text{Hijo } (R_j)$$
$$R_n \mid Padre(R_i) \cup R_i \cup Hijo(R_i)$$

Donde R_n son reglas del tipo: Metareglas, hechos o funciones, reglas o conceptos necesarios para determinar si una regla es verdadera o falsa.

Definición 6. Línea de razonamiento. Sea BC, un conjunto no vacío de reglas, refiere a una secuencia R_1, R_2, …, R_n de elementos de BC es una línea de razonamiento, para cada R_i (i = 1; …; n-1) las reglas derivadas de esta se representan por la función *Hijo* (R_i) que aparece como parte del ancestro presentada como la función Padre (R_{i+1}) de la regla R_{i+1}. Formalmente, R = R_1; R_2; …; R_n es una línea de razonamiento siempre y cuando sea un conjunto finito de reglas:

$$\forall R_i (1 \leq i > n) \in BC,\ \exists\ R_i\ \subset\ Reglas\ \cup MetaR \mid R_i \subset Hijo(R_i) \wedge Padre(R_{i+1})$$

Definición 7. La función eval(Ci) llamada también de *evalua_regla (Ci)*, recoje un conjunto de datos proporcionadas para el caso a evaluar i, dicha función regresa falso (0) o verdadero (1).

$$eval(C_i) = \{1,0\}$$

Donde C_i, es una condición, se describe más adelante.

Ahora se procede a explicar la representación del manejador de reglas en un sistema computacional.

Implantación del manejador de reglas.

De conformidad con la plataforma previamente propuesta, la implantación se divide en dos partes: La creación de la tabla que guarda las reglas y posteriormente el desarrollo de la librería en lenguaje PHP.
La tabla donde ha de residir la BC según definición 5 se guarda en una tabla llamada reglas con atributos que se aprecian en la ilustración 5.

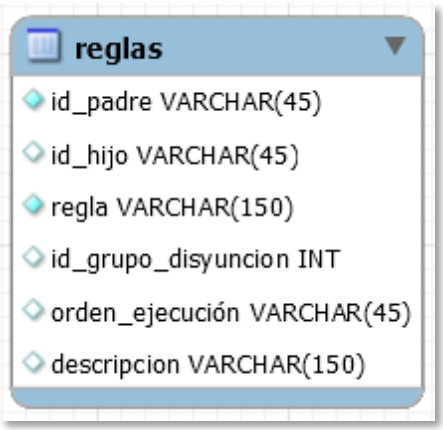

Ilustración 6. Tabla de reglas.
Fuente: Elaboración propia.

De forma breve se explica que los campos *id_padre* e *id_hijo* almacena identificadores, para la regla almacenada en el campo regla, *id_grupo_disyuncion* guarda un identificador único por grupo de reglas con una operación entre ellas de disyunción lógica tal y como se muestra a continuación.

$$\{R_1, R_2, \ldots, R_n\}\ \in\ G_{id\_agrupa} \subset BC\ , n > 1 \mid id\ agrupa\ \in\ \mathbb{Z}^+\ \wedge id\ agrupa > 0$$

Donde $G_{id\ agrupa}$. Es un subconjunto de reglas con un identificador entero positivo para este conjunto de reglas.

El subconjunto $G_{id\ agrupa}$ al ser un conjunto con propiedades disyuntivas y ser evaluada cada regla a través de la función *eval*(R_i), debe cumplir con la siguiente condición para poderse considerar como verdadera.

$$\sum_{i=1}^{n} eval(R_i) > 0$$

Donde n es el número total de reglas en este subconjunto.

De la misma entidad reglas de la ilustración 5, el campo *orden_ejecucion* indica el orden en el que han de evaluarse las reglas, y su importancia radica en que cada regla tarda diferente tiempo en ser trabajada y todas deben ser verdaderas para considerar como verdadera cierta condición, dado que se trata de un subconjunto conjuntivo de tal forma que para ahorrar recursos computacionales, el sistema manejador de reglas debe detener la evaluación o exploración de la BC cuando una regla ya no se cumpla.

En primera instancia se deben de colocar las reglas de más rápida ejecución, para disminuir el tiempo de procesamiento.

Función eval(C_i).

En la definición 7 se explicó de forma general lo que hace la función *eval()*, pero esta función es la más importante del sistema manejador de reglas y por tanto a continuación se describe con detalle.

eval(C_i) recibe cadenas de texto que en lo sucesivo se llamarán condiciones, así como el área de conocimiento en la BC donde trabajará en la correspondiente evaluación, posteriormente determinará si es válida o no (cierta o falsa).

La función *eval(Ci)* está diseñada, para que reciba una cadena de entrada con un formato definido y en dicha cadena recibe los parámetros enviados por el usuario, así como una regla donde precisa el lugar de la base de conocimiento donde deberá evaluar.

Al existir la posibilidad de recibir diferente cantidad y tipo de parámetros en la condición de entrada C_i, se optó por recibir una cadena de texto, y posterior a esto se descompone la regla y a través de un análisis sintáctico se obtiene la información requerida.

En la C_i se manejan dos tipos de datos, el primero es una Regla que permite ubicar el nodo dentro de la BC donde se ha de trabajar, es una especie de índice. Los siguientes datos se refieren a parámetros necesarios y proporcionados por el usuario, agente o aplicación y que sirven para evaluar las reglas en el entorno indicado por la regla de ubicación recibida.

El parámetro de ubicación en si es una regla, dentro de la BC y se maneja como variable que se llama $concepto_cve, para este ejemplo asume el valor de 16, como se puede observar:

$concepto_clave = 16;

Por otro lado, los parámetros proporcionados pueden representar diferentes aspectos, así como una o más variables. Para el siguiente ejemplo se maneja el tiempo en dos variables: minutos y fecha, como se ve puede ver:

$minutos = 5;
$fecha = "2016-06-24";

Cuando ya se han cargado tanto el parámetro de ubicación como las variables a evaluarse en la BC, se procede a construir una cadena de texto, pero respetando cierta sintaxis de un pequeño lenguaje de representación, mismo que puede entender la función *eval(Ci)*. A continuación, se presenta la cadena o condición:

$condicion = "Regla: con_clave = 16, Var:fecha_aplica = $fecha, Var:minutos=$minutos";

Este ejemplo es un caso práctico de construcción, escrito para el lenguaje de programación PHP, por lo que las variables comienzan con $, las palabras reservadas del pequeño lenguaje propuesto son: Regla, Var.

El formato propuesto es:

Regla: $R_1 = \$P_1$**, Var:** $R_2 = \$P_2$**, … ,*Var:*** $R_n = \$P_n$

Donde:

T={Regla, :, =, ‘,’, Var} Son palabras reservadas y en el ejemplo anterior están en negritas.
$Pn, Parámetros proporcionados por el usuario
$Rn, Reglas que ha de trabajar y que pertenecen a la BC.

Este formato usa la coma (,) como separador entre elementos a procesar, para el caso en que dentro de los parámetros exista más de un elemento para cierto tipo de parámetro se usa el separador punto y coma (;) como se aprecia en el siguiente ejemplo:

Regla: $R_1 = \$P_1$**, Var:** $R_2 = (e_1;\ldots;e_m)$**, … ,*Var:*** $R_n = \$P_n$

Donde:

( ) Elementos de lenguaje para representar conjunto de datos.
$P2 es reemplazado por $(e_1;\ldots;e_m)$

Siendo ex, elementos a ser pasados como un subconjunto a la regla, a continuación, un ejemplo:

Var:x=(2;4)

Ya construida la Ci, se transmite a la función *eval()*

$resultado = *evalua_regla($condicion);*

La función *eval(C_i)* producto principal de este trabajo se presenta en el diagrama de flujo en la ilustración 6.

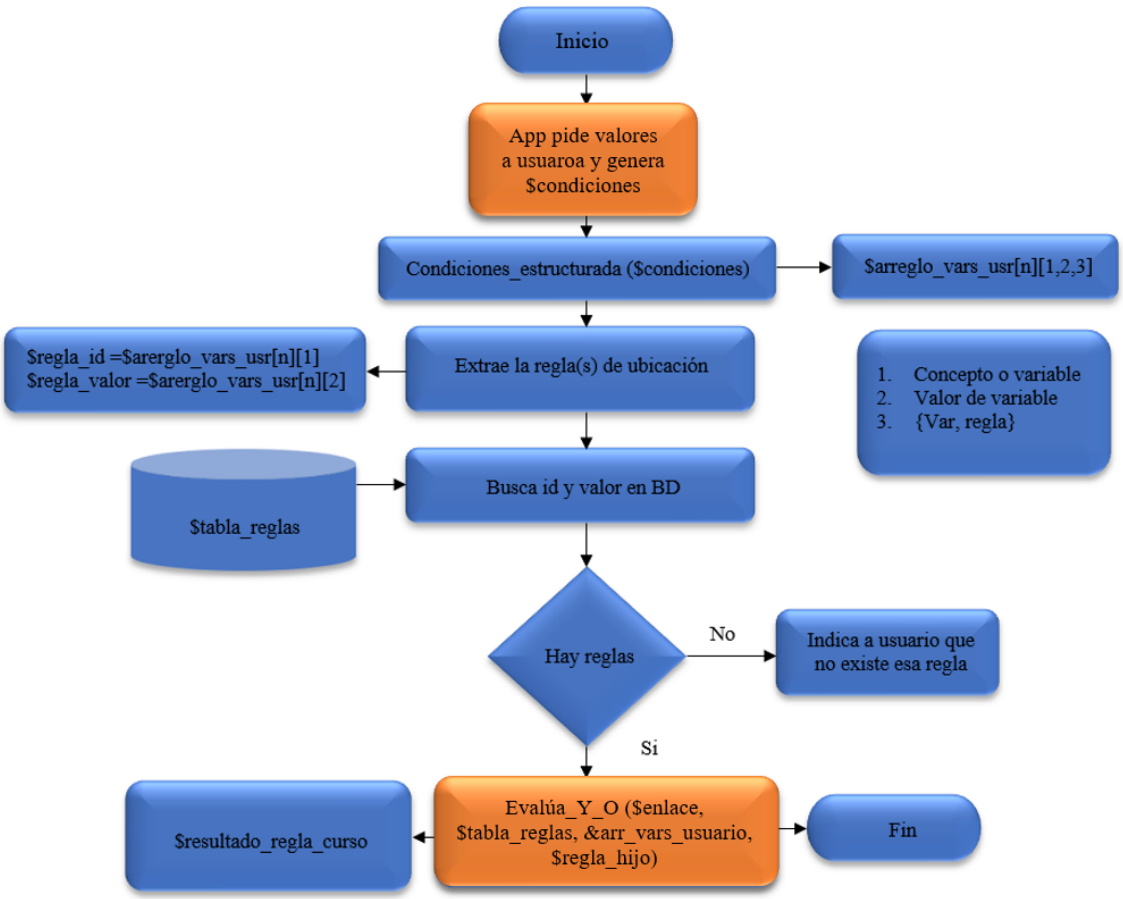

Ilustración 7. Diagrama de flujo de eval(ci).
Fuente: Elaboración propia.

Ahora se da una descripción de los aspectos más importantes del funcionamiento interno de la función *eval()* representado en la ilustración 7.

En esta ilustración se presenta funciones con borde naranja para identificarlas y en color azul lo demás. La función recibe C_i que es una cadena compuesta que incluye los datos del usuario y una regla de ubicación en el árbol de conocimiento, la función *condiciones_estructura(...)* separa variables de reglas y los pasa a un arreglo bidimensional dinámico, llamado $arreglo_vars_usr, posterior a ello con la regla de ubicación, determina una posición en el árbol que contiene la BC, luego extrae las reglas que aprueba el criterio *hijo*(R_i), después se llama la función *Evalua_Y_O(...)* cuyo diagrama de flujo se muestra en la ilustración 8, luego crea un ciclo donde evaluará cada una de las reglas que devolvió la función y continuará mientras el resultado unitario de cada una de ellas sea 1 o verdadero

Ahora se tiene la función propuesta para trabajar con las reglas conjuntivas o disyuntivas como se ve en la ilustración 8, primero desde inicio, procede a buscar si existen reglas en la BC (denotada por $tabla_reglas), cuyo padre sea la regla que se le está pasando, en caso de existir reglas las distingue por que el valor de *regla_tipo* es vacío, luego determina si se trata de una regla del tipo disyuntivo evaluando *id_agrupa* considerando lo siguiente:

$$id\_agrupa \in \mathbb{Z}^+$$

Si cumple la condición procede a buscar las demás reglas con ese identificador posteriormente toma el conjunto de reglas y comienza por ver si la primera del conjunto tiene hijos, en caso afirmativo se llama recursivamente a la función *evalua_Y_O(...)*

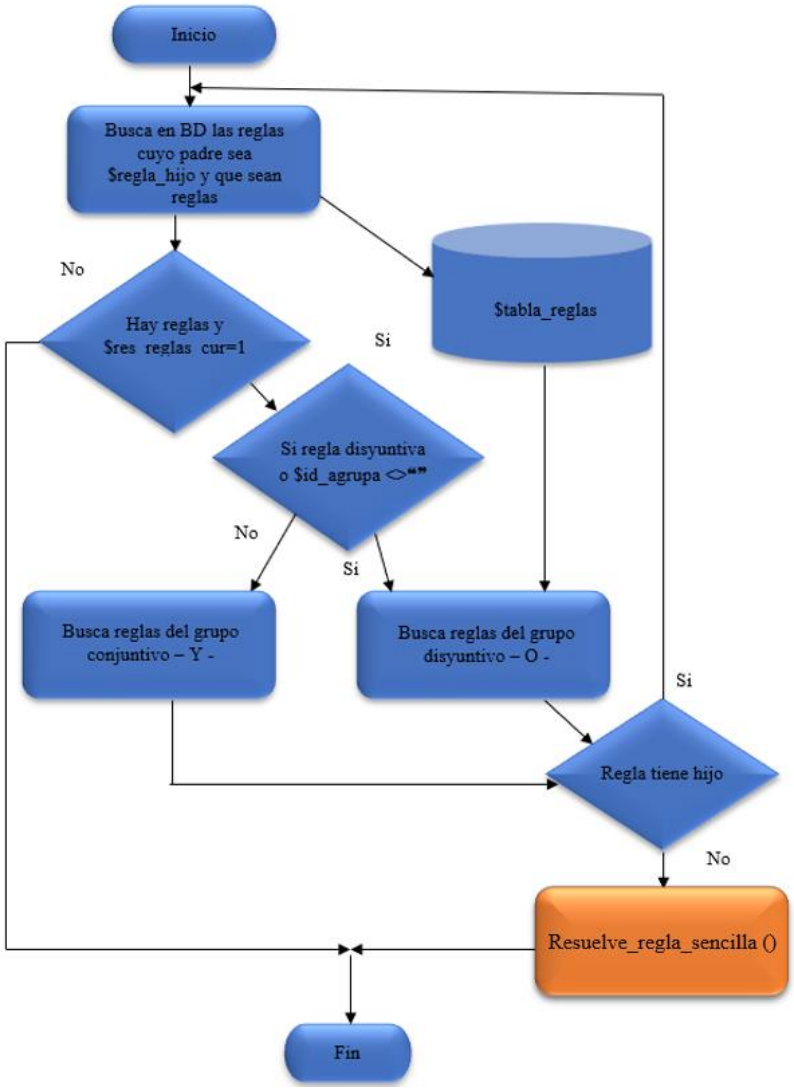

Ilustración 8. Diagrama de flujo de evalua_Y_O(Ci).
Fuente: Elaboración propia.

Caso contrario llama a la función *resuelve_regla_sencilla()* ilustración 9, por otro lado, en caso de que no haya sido una regla disyuntiva, la atiende como regla conjuntiva, después ve si tiene hijos, si es afirmativo se llama recursivamente a la función evalua_Y_O (…), caso contrario llama a la función *resuelve_regla_sencilla()* ilustración 9, como sucedió con las reglas disyuntivas, de esta forma puede explorar en profundidad el árbol de conocimiento o BC.

Ahora se procede a explicar la función *resuelve_regla_sencilla (…)* presentada en la ilustración 9. Para la evaluación de cada regla del conjunto $R_h \epsilon$ hijo (R_i), esta función es cíclica y en resumen toma una regla y la va sintetizando, dicho de otra forma, en cada ciclo resuelve algo y lo reduce hasta el punto en que solo queda cierto o falso, en ese contexto se explica a detalle.

De la ilustración 9, continua si el largo de la cadena es mayor que 1 lo que quiere decir que hay algo que procesar o sintetizar, además que la bandera *$continua_proceso* sea verdadera o 1, caso contrario regresa *$regla valor* y termina la función con el resultado, si continua llama la función *descompone_regla($regla_valor)* y vacía la regla en forma de cadena de texto al arreglo bidimensional *$arr_regla_curso [] []*, que en si descompone la regla elemento por elemento.

Posteriormente llama a la función *Busca_elem_en_vars(…)* cuya función es determinar los elementos de la regla que se identifican como variables y que hayan sido proporcionadas por el usuario a través de la cadena *$condicion*, luego analiza en otra condicional si puede continuar y que todos los elementos hayan podido ser identificados o que se haya determinado la naturaleza del elemento para su posterior tratamiento. La naturaleza de los elementos que se usan para construir reglas se muestra en la tabla 2.

Tabla 2.
Tipos de datos en los elementos de reglas.

Tipo	Descripción
A	Agrupador: (,)
C	Manejo de Conjuntos. Está contenido en …
CB	Es un campo de una tabla en una base de datos
Co	Define constantes
E	Números Entero
ES	Bases de datos (Esquemas)
F	Función implementada en una en lenguaje PHP
FB	Función a con acceso a base de datos
L	Operadores lógicos: disyunción: OR | ó conjunción AND &
OB	Operador para bases de datos para fijar un rango de búsqueda, en el entorno de SQL: BETWEEN
R	Operador de comparación: >, <
S	Separador
T	Representa una tabla en una base de datos
V	Variables proporcionadas por el usuario
Vig	Vigencia de una regla, esta no requiere datos externos

Fuente: Elaboración propia.

Las reglas pueden ser compuestas y se distinguen tres tipos básicos:

- Sección de reglas relacionadas a bases de datos.
- Sección de regla relacionada a operaciones aritméticas
- Sección de reglas con operador relacional entre dos variables, o variable y constante por ejemplo<, >. <>, <=, >=

Con esta propuesta se pueden construir reglas sencillas, pero también reglas más elaboradas para ello se sigue un criterio de evaluación y resolución en forma de árbol, resuelve de forma recursiva, aunque su implantación es con simples ciclos, la reducción de la regla, sigue un orden de precedencia para ir trabajar las operaciones anidadas, empezando por operaciones que devuelvan un valor, tal es el caso de las búsquedas a bases de datos, después el cálculo de funciones implantadas en sistema que igual que las

operaciones a bases de datos devuelven solo un valor, después contempla las operaciones aritméticas dado que ya no existen variables y al final la comparación lógica para determinar su veracidad o falsedad de la regla.

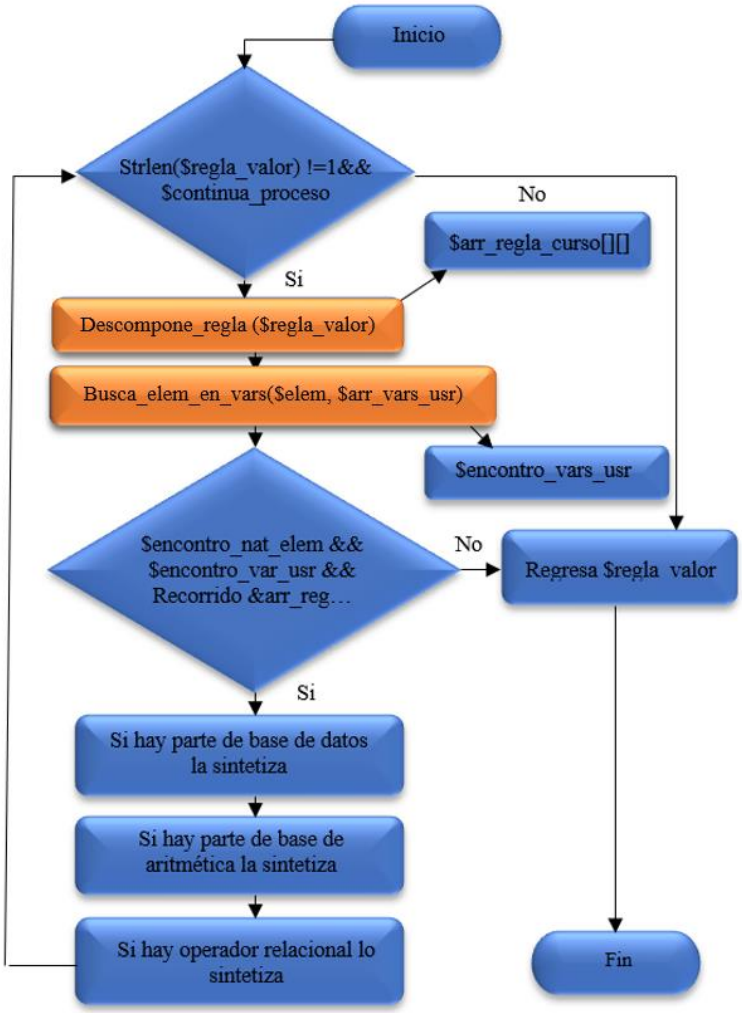

Ilustración 9. Diagrama de flujo de resuelve_regla_sencilla(...).
Fuente: Elaboración propia.

Ahora se procede a explicar los tipos básicos de reglas.

Reglas relacionadas a bases de datos.

Estos tipos de reglas son las más complicadas porque toma la regla que no es SQL estándar y lo convierte a SQL estándar, que hasta el momento puede ser ejecutado por MySQL en sus versiones recientes a la elaboración de este artículo. A continuación, se describe como se realiza este proceso.

Se contemplan dos subtipos:

- Consultas sencillas a BD
- Consultas en las que se involucra funciones de grupo: count(campo de tabla), sum(campo de tabla), max(campo), avg(campo de tabla)

El código SQL se construye a partir de la idea de fragmentar el código acorde al SQL estándar por ejemplo una consulta sencilla se puede construir de secciones constantes y otras variables como se puede ver a continuación:

```
$consulta = "SELECT $componentes_Sel FROM $tabla";
```

Se puede ver que las palabras reservadas *SELECT* y *FROM* permanecerán en las consultas, y $componentes_Sel y $tablas, son variables que se les podrá asignar valores durante el proceso.

En el mismo código se puede apreciar que se está construyendo una cadena que posteriormente será enviada al manejador de bases de datos.

Siendo esta una cadena se puede construir dinámicamente por ejemplo se le puede agregar un condicional a la primera cadena como se ve a continuación:
if(!empty($condi))

$consulta .= " WHERE $condi";

Las consultas pueden generar respuestas de dos tipos, como se ve en los ejemplos siguientes:

SELECT * FROM antilavado.registroop WHERE id_cuenta = 2
SELECT SUM(campo1) FROM antilavado.tabla WHERE id_cuenta = 2;

Para el caso 1 se ha considerado solo decir si es cierto (1) o falso (0), Sin embargo, para el caso 2. Regresa un valor numérico ∈ R.

El problema radica en que las reglas que contienen sección de base de datos pueden regresar 1 o 0, otro regresa un valor para ingresarse en una cadena.

Reglas relacionadas a operaciones aritméticas.

Esta parte procesara reglas o secciones de reglas como:

Var1 + 4 – Var2, u otras operaciones contenidas en op={+, -, *, /}

Reglas con operador relacional.

Para las reglas de comparación o con operador relacional se usa un mecanismo de que simplifica reglas al simple caso de: a operador b, tal que operador = {<, >, <=, >=, <>, =} y en la evaluación solo regresa cierto (1) si se cumple la condición o falso (0) en caso contrario.

A continuación, se presenta la forma de procesamiento y sintetizado de una regla compuesta.

Considere la siguiente regla:

dias_entran + SUMA (dias E num_empleado & tpo_categ & anio_aplica & con_clave C BDincidencias.faltas) < 13

En este caso primero ejecuta la consulta base de datos, *SUMA (dias E num_empleado & tpo_categ & anio_aplica & con_clave C BDincidencias.faltas)* que dice: Suma los días que pertenecen al esquema, tabla BDincidencias.faltas.

- C – Representa que se debe encontrar
- !C Representa que no se debe encontrar.

Luego *Variables_usuario={num_empleado, tipo_categ, anio_aplica, con_clave},* son reconstruidos como condiciones de SQL con los valores pasados por el usuario.

Suponga que el resultado devuelto por el manejador de reglas ha sido 5, entonces ese valor es reemplazado por toda la cadena que lo genero como se ve a continuación:

dias_entran + 5 < 13

Después tal como se ve en la ilustración 8 se vuelve a llamar la función de forma cíclica dado que el tamaño de la regla no es de longitud 1.

Ahora dado que se cuenta con la naturaleza de días_entran y es de tipo 'V' se le asigna el valor proporcionado por el usuario, suponga que vale 2, entonces al reemplazar queda así:

$$2+5 <13$$

Dado que aún no cumple la condición de longitud de tamaño se vuelve regresa después de descomponer la regla en sus elementos se encuentra por orden de precedencia la opción aritmética y procesa la suma de las dos constantes, y reemplaza como se hizo anteriormente quedando de la siguiente forma.

$$7<13$$

Al no cumplir la condición de longitud de la longitud se regresa y vuelve a ejecutar el proceso, pero ahora solo ingresa en la sección de operador relacional lo que devuelve que es cierto ó 1.

Finalmente, la expresión es verdadera por lo que la función *resuelve_regla_sencilla(...)*, regresa 1.

Conclusiones

A la presentación de este artículo el desarrollo de este proyecto ha llevado 10 años, y ha tenido muchos cambios acordes a las pruebas e implantaciones realizadas, asimismo por el nuevo conocimiento adquirido referente a estructuras de datos e inteligencia artificial.

Esta propuesta en la práctica es viable. Como muestra de dicha viabilidad esta propuesta ha sido implantada en el sistema de incidencias del Instituto Politécnico Nacional en México, así como en los trabajos de titulación: "Sistema experto para la detección de padecimientos de la columna vertebral mediante reconocimiento de imágenes y procesamiento del historial clínico" (Mariscal Avendaño & Mendoza Ruíz, 2021), "Sistema WEB para la administración de incidencias del personal, adaptable a diversos tipos de organización" (Fuentes Arteaga & Miranda Quintero, 2024), "Nephro-healthcare- Aplicación móvil de apoyo para personas con Insuficiencia Renal Crónica" (Solis, 2022), "Sistema experto web aplicado a orientación vocacional para alumnos aspirantes al IPN en nivel Superior" (Orta Cisneros et al., 2022) y en la tesis doctoral titulada "Sistema experto para la detección de transacciones bancarias sospechosas de lavado de dinero" (Sabas González, 2019).

Derivado de la implementación del evaluador de reglas propuesto en un entorno de producción, en el área de recursos humanos en el Instituto Politécnico Nacional en México, con 100 usuarios concurrentes, se obtuvieron los siguientes resultados: Se contabilizaron 514293 evaluaciones de las reglas diversas, incluidas consultas a bases de datos que son las más lentas, con un tiempo promedio de 0.042 segundos por evaluación, lo cual se indica que el tiempo promedio por regla es menor al segundo.

También se puede concluir que esta propuesta soporta muchas reglas, de diferente tamaño y complejidad, aunque lo recomendable es construir reglas sencillas, aunque sean más. También se pudo implantar reglas referentes a la temporalidad y veracidad de las reglas en diferentes entornos.

En trabajos futuros se contempla:

- Disminuir el tiempo de ejecución.
- Crear interfaz gráfica e intuitiva para creación de reglas que conserven la integridad de la BC.
- Ampliar funcionalidad en código SQL.

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Interaction between interior space and environment: Current research and trends evaluation

İç Mekân ile Çevre Arasındaki Etkileşim: Güncel Araştırmalar ve Eğilimlerin Değerlendirmesi

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Abstract

Interior space is where individuals live, interact with their immediate environment, and carry out their daily activities. Individuals can only meet their social, psychological, and physiological needs in spaces designed accordingly. The adaptation of living spaces to individuals depends directly on their relationship and interaction with the interior space and its environment. Therefore, the interior space in which an individual lives cannot be considered independently of its surroundings. This study examines the interaction between interior space, individuals, and their immediate environment, focusing on the contribution and significance of the environment in the design of space. To achieve this objective, a bibliometric analysis method will be employed. Existing literature on space design and environmental interaction will be systematically reviewed, analyzing academic publications, citation networks, and thematic trends. This analysis will identify key contributions to the role of the immediate environment in space design, emerging research areas, and gaps in current knowledge. By adopting this methodological approach, the study provides a comprehensive, data-driven perspective that better understands the dynamics between interior spaces, individuals, and their environment.

Keywords: Environment, Interior Space, Bibliometric analysis, Interior Space-Environment Interaction, Interior Design.

Özet

İç mekân, bireylerin yaşadığı, yakın çevresiyle etkileşime geçtiği ve günlük aktivitelerini gerçekleştirdiği alandır. Bireyler ancak bu doğrultuda tasarlanmış mekânlarda sosyal, psikolojik ve fizyolojik ihtiyaçlarını karşılayabilirler. Yaşam alanlarının bireylere uyumu, doğrudan iç mekân ve çevresiyle kurulan ilişki ve etkileşime bağlıdır. Bu nedenle, bireyin yaşadığı iç mekân çevresinden bağımsız düşünülemez. Bu çalışma, iç mekân, birey ve yakın çevre arasındaki etkileşimi inceleyerek, çevrenin mekân tasarımına katkısını ve önemini ortaya koymayı amaçlamaktadır. Bu amacı gerçekleştirmek için bibliyometrik analiz yöntemi kullanılacaktır. Mekân tasarımı ve çevresel etkileşim konularında mevcut literatür sistematik bir şekilde taranacak; akademik yayınlar, atıf ağları ve tematik eğilimler analiz edilecektir. Bu analiz sayesinde, yakın çevrenin mekân tasarımındaki rolüne dair temel katkılar, ortaya çıkan araştırma alanları ve mevcut bilgi birikimindeki boşluklar belirlenecektir. Bu metodolojik yaklaşım sayesinde çalışma, iç mekân, birey ve çevre arasındaki dinamikleri daha iyi anlamaya yönelik kapsamlı ve veriye dayalı bir bakış açısı sunacaktır.

Anahtar Kelimeler: Çevre, İç Mekân, Bibliyometrik Analiz, İç Mekân-Çevre Etkileşimi, İç Mimarlık.

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Introduction

The relationship between the architectural environment and the individual is significant throughout every stage of life. Individuals continuously observe, interpret, and reshape their environments in response to their evolving needs, values, and expectations. This is not a static interaction; it is a dynamic, reciprocal process of adaptation and decision-making, through which space transforms into a living, personalized environment shaped by human presence and intent. Within this broader context, interior space emerges as the most immediate and influential domain through which this relationship is experienced and negotiated.

Interior space, as the most immediate physical layer of human experience, plays a pivotal role in mediating this relationship (Prince, 2014). It is within interiors that daily routines unfold, psychological needs manifest, and a sense of belonging is either reinforced or undermined. The interaction between interior space and its broader environmental context thus reflects a multidimensional necessity: the creation of spatial arrangements that align not only with functional requirements but also with emotional and cultural meaning. As Aygenç (2020) highlights, this is a "dynamic interaction" where both the individual and the environment mutually influence one another in an ongoing cycle of spatial exchange. However, while the centrality of interior space is widely acknowledged, scholarly approaches often fall short of addressing its connection to the surrounding environment in a cohesive manner.

Although scholarship on environmental design has grown in recent decades, a notable gap persists. Specifically, there is a lack of integrative, user-centered approaches that systematically link interior spaces with their immediate environments in both theoretical and empirical terms. This fragmentation limits designers' ability to develop holistic spatial solutions and constrains our understanding of how environments function as interconnected systems of human experience. Furthermore, very few studies have employed data-driven techniques—such as bibliometric analysis—to trace conceptual developments or identify thematic patterns in this domain (Tabatabaeifard et al., 2025; Gauer, 2024). To bridge this methodological and conceptual divide, the present study proposes an analytical framework that centers on spatial interaction.

This study aims to address that gap by exploring the role of interior–environment interaction within the design process. Given that interiors represent the first and most personal interface between individuals and their built environment, understanding how these spaces operate in concert with their surroundings is crucial for promoting spatial comfort, well-being, and long-term usability. Accordingly, this research adopts a bibliometric analysis methodology to examine the literature on interior and environmental interaction, mapping dominant themes, research gaps, and intellectual trajectories. Building upon these insights, the study also seeks to translate its findings into actionable knowledge for spatial design practice.

By clarifying these spatial dynamics, the study seeks to provide practical insight for architects and interior architects. Its findings are intended to inform user-centered design strategies and support evidence-based decision-making in a range of design contexts, ultimately contributing to more adaptive, inclusive, and context-sensitive spatial practices.

The remainder of the paper is structured as follows: Section 2 presents the theoretical framework that informs interior–environment interactions. Section 3 outlines the bibliometric methodology and data set. Section 4 discusses the results and thematic trends. Finally, Section 5 offers a discussion of implications and concludes with recommendations for future research.

Theoretical Framework

The relationship between interior space and the individual is not merely a physical interaction; it also encompasses psychological, emotional, and social dimensions. Considering that people spend a significant portion of their lives within built environments, the design of interior spaces becomes critically important, particularly in terms of health and well-being (Araya León et al., 2022; Mahmoud, 2017).

Recent studies have shown that designing interior environments in alignment with individual needs plays a crucial role in meeting psychological requirements such as safety, privacy, a sense of belonging, and identity. In this design process, the expertise of architects and interior designers extends beyond aesthetics to include the creation of psychologically supportive, user-centered environments (Malik & Jamil, 2019).

Furthermore, the integration and transition between interior space and the external environment significantly shape the quality of an individual's relationship with their surroundings. This highlights the necessity of designing not only interior spaces but also their broader environmental context with sensitivity to users' spatial experiences (Sameh, 2015).

In studies focused on individuals with disabilities, the accessibility and usability of interior environments have been directly shown to impact individual participation and quality of life. In this regard, universal design principles aim to create inclusive environments that are responsive to user diversity (Cassi et al., 2021).

Recent discussions in the field have also emphasized the limitations of traditional design models that treat interior and exterior spaces as isolated domains. In contrast, contemporary theories now advocate for an integrative approach, where the permeability, continuity, and overlap between spatial layers are central to user experience. These ideas are increasingly relevant in the context of post-pandemic housing, hybrid work environments, and the mental health implications of spatial confinement (Tabatabaeifard et.al., 2025).

Finally, various theoretical paradigms—objectivist, relativist, and critical—provide insight into the values and assumptions that shape design thinking. These theoretical perspectives help us to conceptualize interior space design not only as a physical production process but also as a socio-cognitive interaction (Gauer, 2024). For instance, while objectivist paradigms emphasize measurable spatial attributes such as ergonomics or lighting levels, critical paradigms draw attention to power dynamics, identity politics, and cultural symbolism embedded in design decisions.

This multilayered theoretical perspective offers a comprehensive framework for understanding the interaction between individuals and their interior environments. However, while these theoretical insights are invaluable, they remain largely conceptual. They often lack empirical mapping of how these themes have evolved, intersected, or diverged across disciplines over time.

To address this gap, the present study adopts a bibliometric analysis method to evaluate academic production on interior–environment interaction quantitatively and to uncover prevailing trends and knowledge gaps in the field. This method enables the identification of influential works, thematic clusters, and underexplored areas, thus bridging the gap between theory and empirical insight. In the following section, the methodological approach, including data sources, selection criteria, and analysis tools, is described in detail to demonstrate how the bibliometric study was structured and conducted.

Methodology

From the past to the present, the number of academic publications has been increasing daily, making it difficult for academics, students, and individuals interested in science to research related subjects and identify the deficiencies in the literature. Evaluating issues related to bibliometric analysis is a quantitative approach used to determine the current situation in the literature in terms of authors and topics (Gauer, 2024; Araya León et al., 2022; Wang et al., 2021). In this context, bibliometric analysis provides insight into the current situation and development aspects in research areas, enabling researchers to strategically position their work and make original contributions to the literature. Especially in interdisciplinary studies, it enables the discovery of new research opportunities by visualizing the interactions and information flow between different fields (Karunan et al., 2017). In this study, all bibliometric relationships related to the interaction between humans and the environment are presented to reveal the contribution of the interaction between interior space and the immediate environment to the design of space. The sequential structure of the methodological steps followed in this study is illustrated in Figure 1 below.

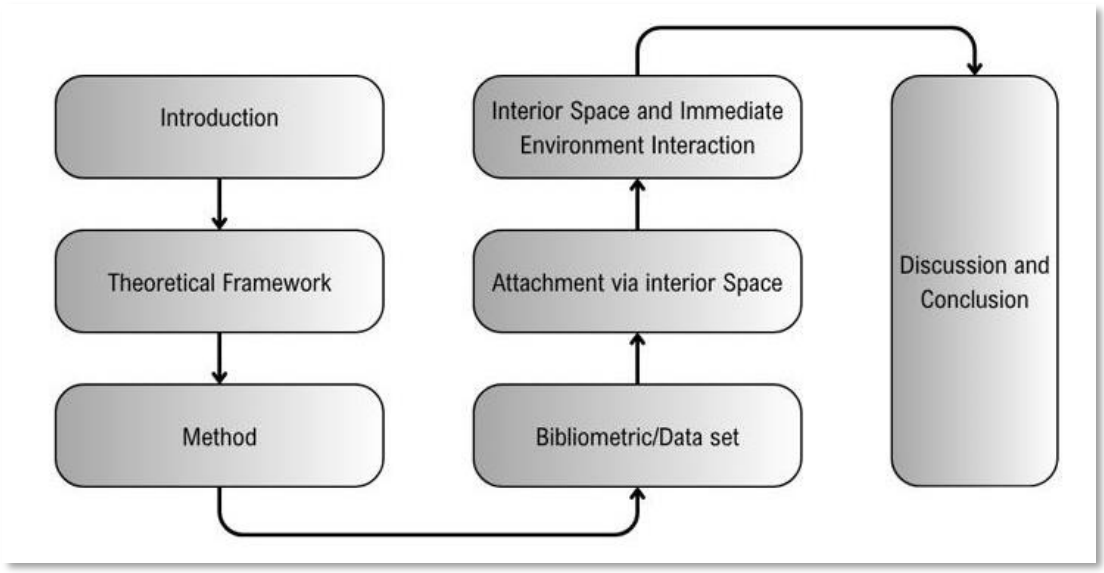

Figure 1. Flowchart of the study.
(Source: Author's work)

In examining these relationships, the Web of Science (WoS) database was preferred because it provides reliable and comprehensive data and high-quality and reliable metadata. The data set was constructed using a defined set of search terms and filters (see Table 1). Duplicates, incomplete entries, and irrelevant documents were systematically excluded by cross-checking DOIs, author names, and publication types. Data cleaning was performed in R-Studio using Biblioshiny tools to ensure consistency and accuracy in metadata fields such as keywords, author affiliations, and citation counts. Additionally, given the challenges in developing and merging concurrent databases, a rigorous evaluation strategy was followed in the analysis process.

All data used in this study were retrieved from publicly accessible academic sources (WoS) and did not involve any personal or sensitive information. Therefore, the research did not require institutional ethical approval. Nevertheless, data handling was conducted in line with the principles of academic integrity, transparency, and responsible research conduct.

Table 1.
Wos based research criteria

Parameters	Information
Database	Web of Science Core Collection
Software	R-Studio-Biblioshiny
Keywords:	TS=("Spatial Design" OR "Architectural Space" OR "Built Environment") AND TS=("Human-Environment Interaction" OR "Sense of Place" OR "Proximal Environment") Refined by: (Research Areas: (Architecture OR Urban Studies
Web of Science Category	
Document Type	All type
Research Areas	Architecture OR Urban Studies

(Source: Author's work).

Results

Conceptual Themes in Literature

The documents used in the study span the period from 2001 to 2025. The data were collected from 33 sources, including articles, book chapters, and 44 documents. Upon examining the publication types, 31 articles, four book chapters, three early access articles, four papers, and two reviews were identified. It

shows that most of these publications are research articles (70%). The average citation per document is 18.84, and the total number of references is 2134. The number of authors working on the subject is 93, and the number of authors writing articles with a single author is 20.

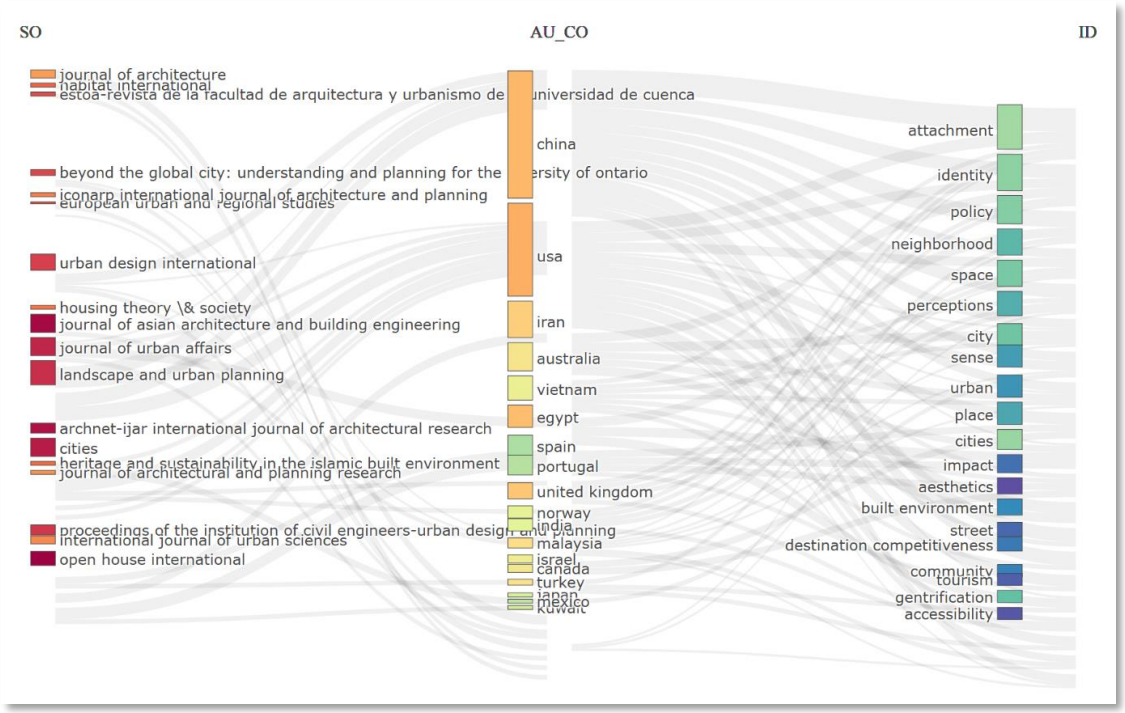

Figure 2. Three-field plot analysis.
(This figure was generated by the authors through the use of Biblioshiny software)

When three-field plot analysis is examined (in terms of country-source-keyword), China, the USA, and Iran are at the top of the list (Figure 2). Attachment, identity, and policy were the keywords most frequently used when examining the keywords.

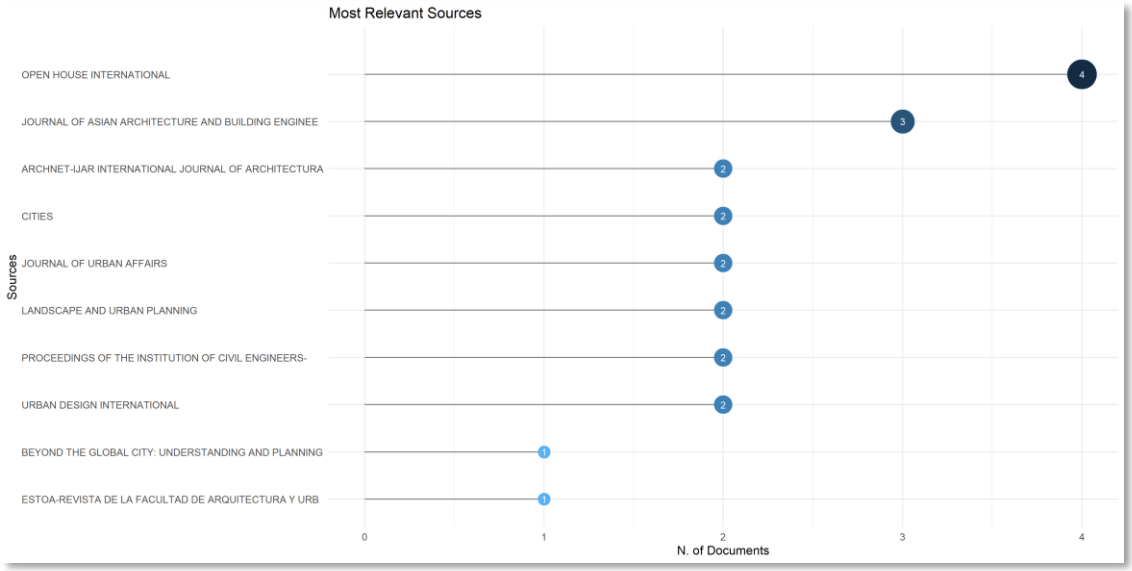

Figure 3. Most relevant sources.
(This figure was generated by the authors through the use of Biblioshiny software.)

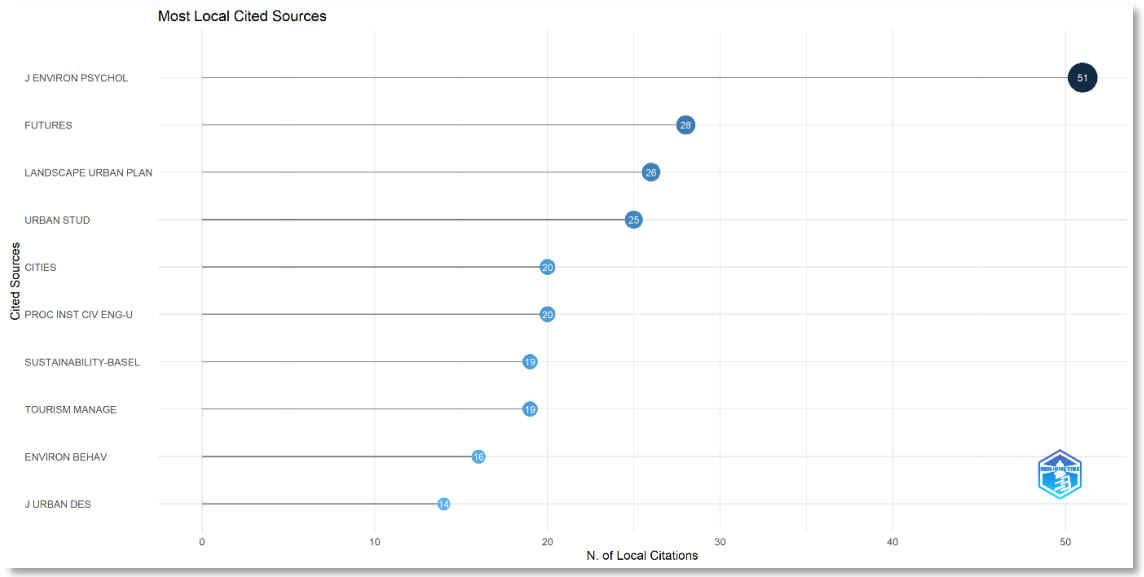

Figure 4. Most local cited sources.
(This figure was generated by the authors through the use of Biblioshiny software.)

Among the 44 documents examined due to the scans, the most relevant sources were Open House International and the Journal of Asian Architecture and Building Engineering. An average of two documents were identified in the journals examined in these scans (Figure 3). The most frequently cited sources in the reference list were the Journal of Environmental Psychology (51 citations), the Journal of Asian Architecture and Building Engineering (28 citations), Landscape and Urban Planning (26 citations), and Urban Studies (25 citations) (Figure 4).

Table 2.
Examining the Resource Effect

Source	h_index	g_index	m_index	TC	NP	PY_start
OPEN HOUSE INTERNATIONAL	3	4	0,176	19	4	2009
ARCHNET-IJAR INTERNATIONAL JOURNAL OF ARCHITECTURAL RESEARCH	2	2	0,222	11	2	2017
CITIES	2	2	0,4	73	2	2021
LANDSCAPE AND URBAN PLANNING	2	2	0,25	437	2	2018
URBAN DESIGN INTERNATIONAL	2	2	0,286	18	2	2019
ESTOA-REVISTA DE LA FACULTAD DE ARQUITECTURA Y URBANISMO DE LA UNIVERSIDAD DE CUENCA	1	1	0,125	1	1	2018
EUROPEAN URBAN AND REGIONAL STUDIES	1	1	0,167	9	1	2020
HABITAT INTERNATIONAL	1	1	0,045	20	1	2004
HOUSING THEORY \& SOCIETY	1	1	0,091	150	1	2015
ICONARP INTERNATIONAL JOURNAL OF ARCHITECTURE AND PLANNING	1	1	0,111	1	1	2017

(This table was generated by the authors through the use of Biblioshiny software.)

As a result of the analysis of the source impact (Table 2), it was determined that Open House International had the highest global citation count. Archnet-IJAR follows this journal: International Journal of Architectural Research and Cities, respectively.

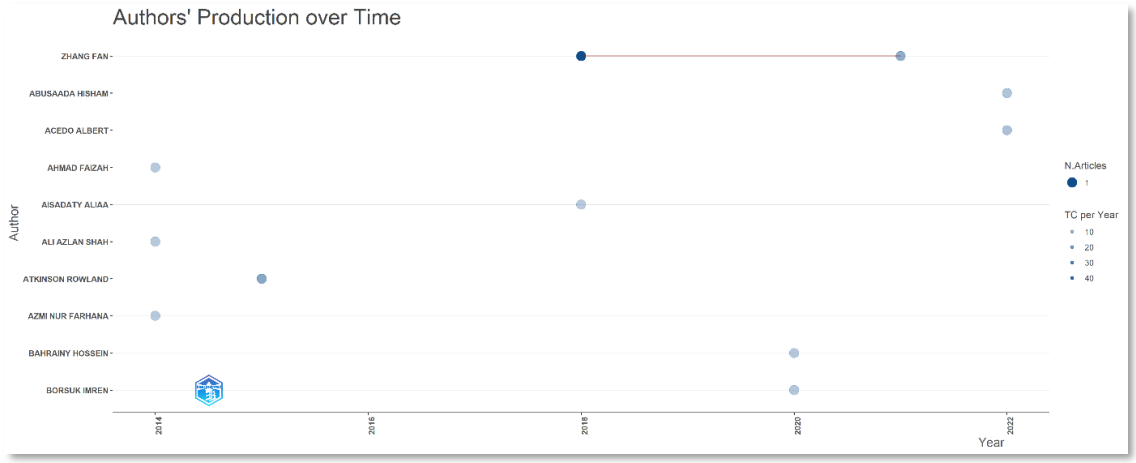

Figure 5. Production of authors over time.
(This figure was generated by the authors through the use of Biblioshiny software.)

Table 3.
Most Relevant Authors

Authors	Articles	Articles Fractionalised
ZHANG FAN	2	0,31
CARLO	1	0,17
JIAYU	1	0,14
ABUSAADA HISHAM	1	0,50
ACEDO ALBERT	1	0,33
AHMAD FAIZAH	1	0,33
AISADATY ALIAA	1	1,00
ALI AZLAN SHAH	1	0,33
ATKINSON ROWLAND	1	1,00
AZMI NUR FARHANA	1	0,33

(This table was generated by the authors through the use of Biblioshiny software.)

According to Table 3, Zhang Fan is the author with the most publications on this topic. These publications have been carried out since 2018. Examining the publications produced by the authors over time (Figure 5), it is evident that the intensity occurred between 2014 and 2022. In this regard, it can be noted that interest in the subject has increased in recent years.

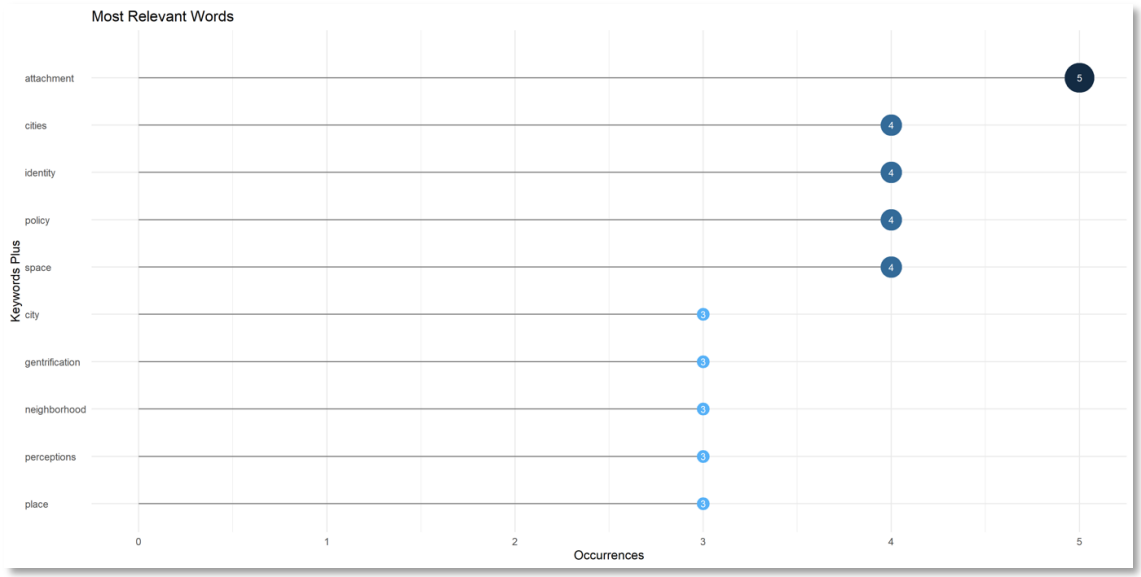

Figure 6. Most relevant words.
(This figure was generated by the authors through the use of Biblioshiny software.)

The most common keywords in the examined documents were Attachment (5), Cities (4), Identity (4), Policy (4), Space (4), City (3), Gentrification (3), Neighborhood (3), Perceptions (3) and Place (3) (Figure 6). It was determined that the keyword most frequently used by the authors was 'attachment.'

Figure 7. Concurrency network.
(This figure was generated by the authors through the use of Biblioshiny software.)

Co-occurrence networks are graphical representation tools that show how often variables appear together. A co-occurrence network can analyze many pairs of co-occurring variables simultaneously. In these networks, each variable is represented as a node or point, while the co-formation between two variables is expressed by an edge or link that connects the nodes. The size of the nodes (Figure 7) indicates the frequency with which the terms are repeated. In the Space and Environment literature, as the number of co-occurrence keywords increases, the size of the nodes also increases. The distance between the individual pairings reflects the similarity and comparative strength of the subjects. Different colors indicate individual clusters.

Figure 7 shows a network of five unique clusters representing different subfields of Space and Environment study:

Cluster 1 (Blue): Includes Attachment, Policy, and Destination Competitiveness studies.
Cluster 2 (Purple): Focuses on Space, Identity, Built Environment.
Cluster 3 (Green): Includes work on Community and perceptions.
Cluster 4 (Red): Focuses on Neighborhood.
Cluster 5 (Orange): Urban covers Cities (Figure 7).

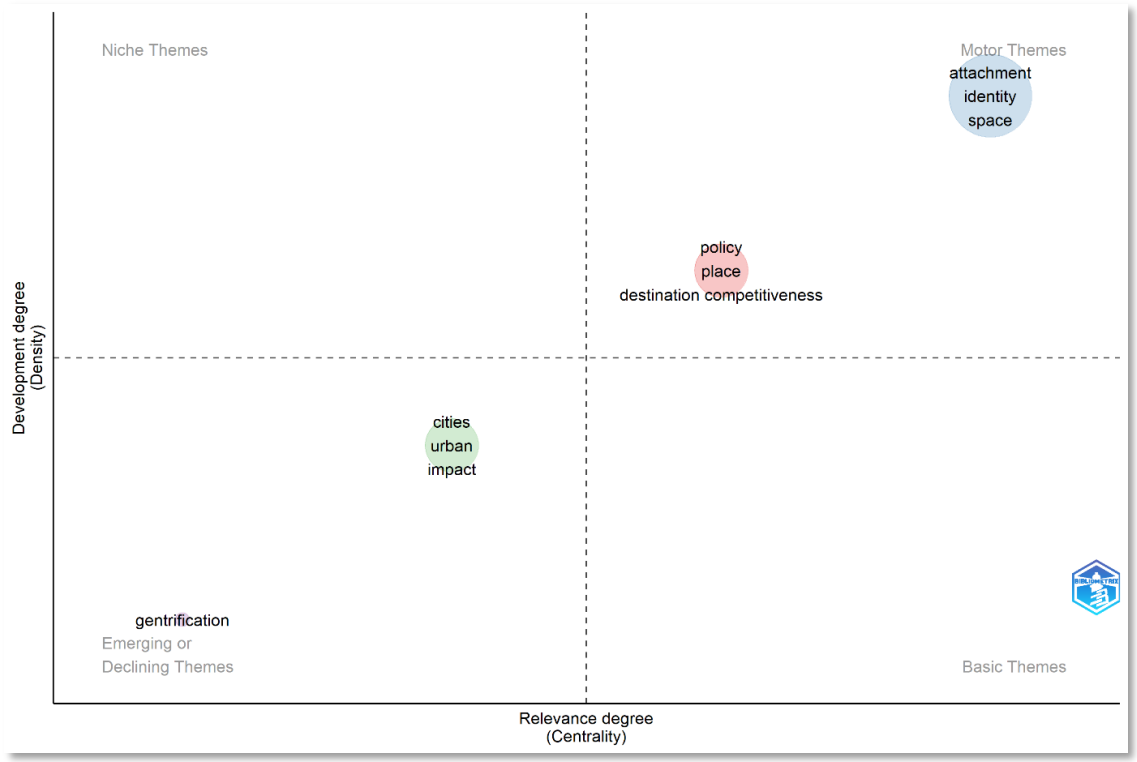

Figure 8. Thematic Map Via Keywords.
(This figure was generated by the authors through the use of Biblioshiny software.)

Thematic maps compile relevant information by focusing on a specific topic and visualizing the relationship between these themes and spatial locations. The thematic map, based on keyword analysis (Figure 8), shows that keywords are distributed across four quadrants. Words such as Attachment, Identity, Space, Policy, Place, and Destination Competitiveness constituted the main themes, while Cities, Urban, and Impact were among the other important themes. However, no keywords associated with simple themes and niche themes were found in this study.

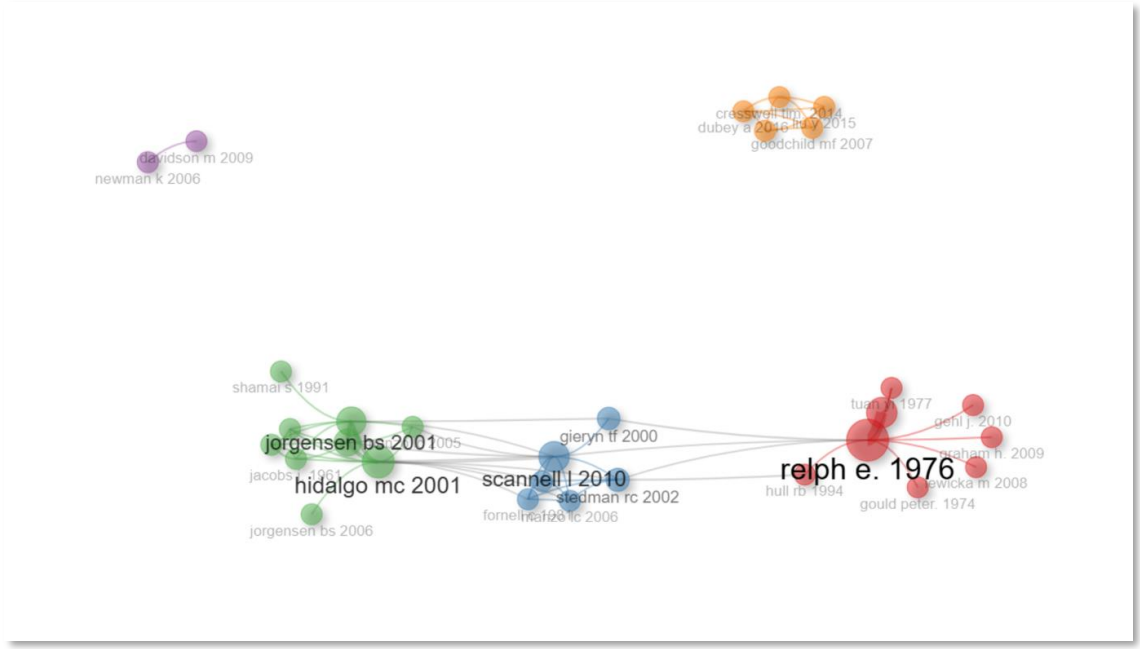

Figure 9. Common Citation Analysis
(This figure was generated by the authors through the use of Biblioshiny software.)

Co-citation is a semantic similarity metric for documents that use citation relationships, similar to Bibliographic Linking. The frequency with which other documents mention two texts together is defined as the joint citation. The common citation analysis is illustrated in Figure 9, where each circle represents a citation network in the Space and Environment literature. The size of the circles reflects the volume of citations; The larger the circle, the more citations the respective author's articles have received. Additionally, the proximity of the apartments to each other suggests a strong relationship between the jointly cited documents.

Discussion

Understanding Attachment in the Context of Interior and Surrounding Environments

The bibliometric analysis results indicate that "attachment" is one of the most frequently recurring concepts in literature. This finding aligns closely with the theoretical framework, particularly about the emotional bonds individuals form with interior spaces. Interior environments have the potential to support the construction of identity, psychological security, and a sense of belonging. In studies where the attachment is emphasized, residential layouts, neighbourhood-level continuity, and customizable spatial elements are noted to enhance user experience.

This result supports earlier findings by Williams & Kitchen (2012), who associate strong place attachment with improved well-being and community engagement. Similarly, Prince (2014) highlights the role of interior environments in shaping individuals' future aspirations and sense of agency. However, while these studies adopt qualitative or psychological lenses, the current analysis contributes a broader, data-driven perspective by quantifying the prominence of attachment across multiple sources and disciplines.

Moreover, attachment here emerges not as an isolated concept but as a node within a larger co-occurrence network involving identity, policy, and space. This relational positioning suggests that attachment is increasingly framed in literature not only as an emotional state but as a design-relevant construct with policy and planning implications. Such insight offers a foundation for theorizing attachment beyond phenomenology — as a multi-scalar mechanism influencing spatial configuration and user engagement.

For example, frequently cited publications suggest that attachment in spatial design transcends physical arrangement, incorporating users' personal histories, cultural backgrounds, and symbolic relationships. This demonstrates that space is not merely a physical construct but also a psychosocial one. Accordingly, spatial

design must accommodate the multifaceted nature of attachment, promoting flexible, participatory, and culturally sensitive design approaches that support emotional bonds between individuals and their environments.

This perspective is echoed in the work of Small & Adler (2019), who argue that spatial attachment is both shaped by and reflective of the social ties formed within specific environments. Similarly, Araya León et al. (2022) emphasize that psychological well-being is significantly influenced by the extent to which interior spaces accommodate users' personal and cultural narratives.

What distinguishes the present study, however, is its empirical demonstration of how "attachment" functions not in isolation but in strong co-occurrence with other themes such as policy, place, and identity—suggesting that attachment is increasingly recognized as a critical mediator between spatial planning and lived experience.

By identifying "attachment" as a structurally central node within the bibliometric network, this study elevates its status from a subjective design concern to a strategic design driver. For practitioners, this suggests the need to integrate emotional resonance and symbolic meaning more intentionally into spatial programming, particularly in residential and community-based projects.

To deepen the understanding of these dynamics, it becomes necessary to clarify what is meant by "environment" in academic discourse. The relationship between attachment and space is not confined to physical boundaries but unfolds within a broader environmental context. Scholarly literature defines "environment" as a multidimensional concept that encompasses physical, biological, social, economic, and cultural dimensions (Lyu et al., 2023). This comprehensive view enables the examination of interior spaces not in isolation but as distinct yet interconnected components within larger environmental systems, providing a robust foundation for understanding how attachment is both shaped by and shapes interior environments.

Environmental elements collectively form the environment, which can be broadly classified into two categories relevant to this study: the interior, representing the immediate physical environment closest to humans, and its adjacent environments, which encompass broader contexts closely related to interiors. Thus, interiors and their immediate surroundings constitute the defined physical environment for humans.

The environments humans inhabit vary symbolically and formally, shaped by cultural, geographical, and temporal factors. Therefore, humans simultaneously experience their environments through physical and socio-cultural dimensions (Tam & Milfont, 2020).

Rapoport (1977) categorizes environments into five types based on their characteristics: individual, physical, personal, suprapersonal, and social environments. The individual environment involves direct experiences and interactions. The physical environment includes geographic, climatic, and constructed elements that either facilitate or limit behaviour. Personal environments encompass influential social relationships such as family, friends, authority figures, and peer groups. Suprapersonal environments are shaped by the demographics and lifestyles of their inhabitants, including age, social class, ethnicity, and lifestyle. Lastly, the social environment reflects societal norms and institutional structures.

This categorization underscores two critical aspects of understanding the environment: its multilayered nature incorporating social, cultural, and physical dimensions, and the reciprocal relationship between the changing characteristics of the physical environment and spatial organization (Figure 10).

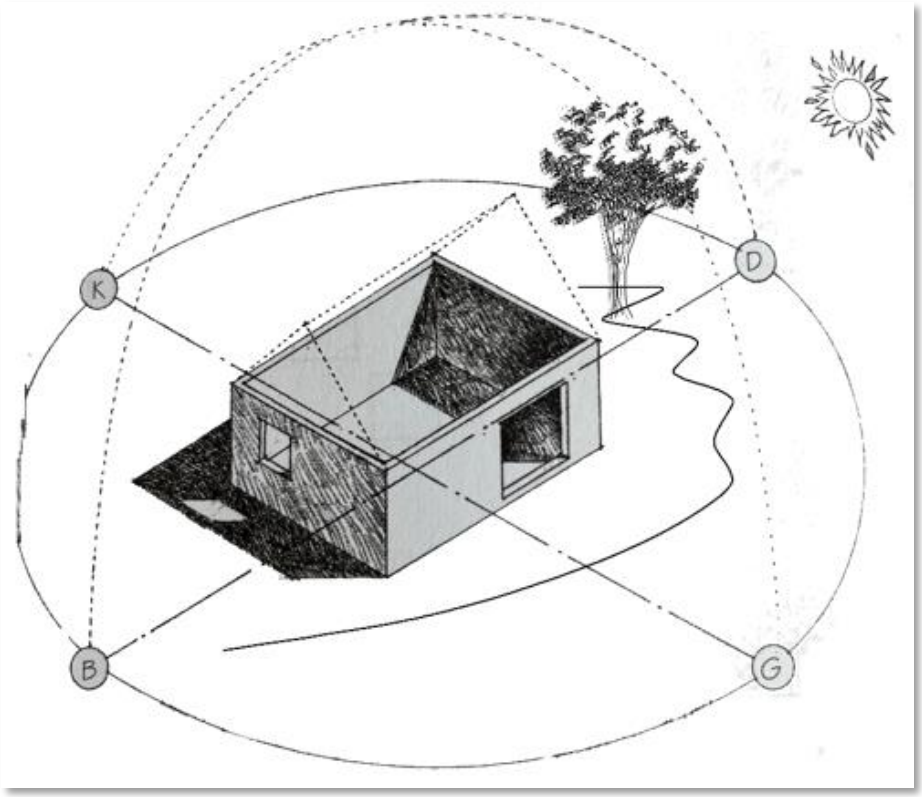

Figure 10. There is a link between the changing characteristics of the physical environment and interior space.
(Source: Author's work)

Interior space formation directly reflects the multilayered social, cultural, and physical characteristics of the environment. This interplay influences the form, functionality, and design of spaces, emphasizing the importance of understanding both physical and conceptual dimensions.

While traditional views often define space by its physical size and measurable features, contemporary discourse recognizes space as encompassing both physical and conceptual dimensions. Physical space involves boundaries, dimensions, and tangible elements. Conceptual space, conversely, includes social, cultural, and relational dynamics that guide human interactions and activities within it (Small & Adler, 2019).

Thus, the creation of concrete space cannot be viewed independently from its users. Instead, space formation must be evaluated in conjunction with human-environment interactions. This perspective leads to two central insights:

- Space is inherently multidimensional.
- Space cannot be understood independently of the life occurring within it (Çubuk et al., 1977; Oğuz, 1994).

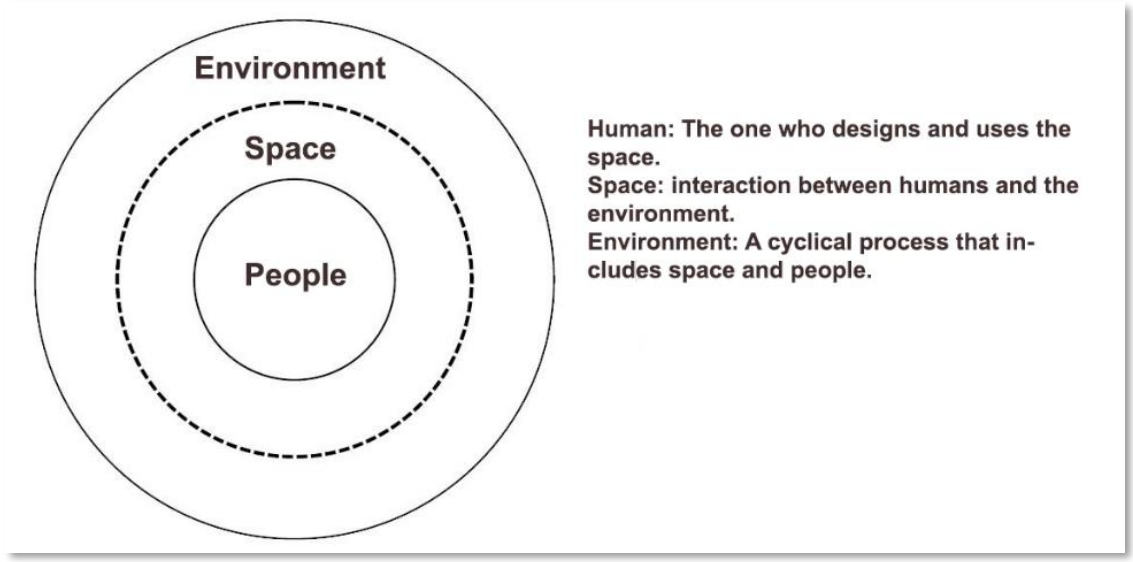

Figure 11. Human- Space-Environment interaction.
(Source: Author's work)

Space, therefore, is defined by human interactions, relationships, and associated infrastructure, framed by cultural, symbolic, and experiential conditions (Aksoy & Çebi, 2024). Humans are active subjects shaped and influenced by their environment, with the environment arising from human-environment interactions. Hence, space represents an environment specifically curated for human existence.

Modern living conditions, evolving human needs, and technological advancements necessitate a redefinition of the physical attributes of space. Utilitarian approaches highlight the need to evaluate space objectively and subjectively. Objective space is defined by its measurable three-dimensional attributes, corresponding to interiors. In contrast, subjective space is understood through sensory perception and experiences corresponding to external environments. Furthermore, spaces can be classified based on their level of privacy or social function, which influences their boundary flexibility or rigidity.

This refined perspective facilitates a nuanced exploration of human-environment interactions, enriching the understanding of how attachment shapes and is shaped by interior spaces.

Interior Space and Immediate Environment Interaction

There will be environments in which people live throughout their lives. Its relationship with its environment will continue to a certain extent and continuously. Thus, man and his environment will continue to exist in a cyclical process. Because human needs are constantly evolving, new requirements will necessitate the production of continuous solutions to meet these new needs (Aygenç, 2020).

Spaces that are in a direct or one-to-one relationship with humans and their environment are considered interiors. People spend most of their lives in these areas. Therefore, it is expected to meet all the needs and requirements of the interiors. Designing interiors that cater to all these requirements and needs is a collaborative process involving both the designer and the user (Nguyen, 2024).

Interiors play a significant role in shaping human-environmental relations. In the design process of a space, the following points should be considered:

- The structure of the environment in which the space will be shaped,
- Behavioural and cultural characteristics of users in space,
- The effects of spatial elements on the user,
- The relationships established by the components between human and space with each other,
- The effects of an individual's belonging to a space on the shaping of that space in spatial design.

In line with these principles, it is not enough to evaluate the space solely on an indoor scale; it must also be considered in conjunction with its immediate surroundings. This comprehensive approach enables a deeper understanding of the physical, social, and cultural context of the space. It enables a more holistic analysis of the interactions between the space and its surroundings during the design process. The relationship between the space and its surroundings has important dynamics in terms of user experience, perceptual dimensions, and functionality. In this context, the interaction of space with its immediate surroundings has been discussed in the light of various academic studies and evaluated from different perspectives (Aygenç, 2020; Ittelson et al., 1974).

The relationship between people, interior space, and the environment is in constant transformation. In this relationship, humans are the fundamental element that establishes the connection between interior space and environment, and cultural dynamics shape this process. While human-environment interaction gives meaning to the space, the space emerges as a physical reflection of this interaction. In short, interior space is a unity that the environment offers to human beings and is interpreted by them.

Interiors, in particular, play a significant role in the lives of individuals. On the one hand, people benefit from the environmental solutions developed by designers; on the other hand, they strive to create an environment in which they can feel comfortable and belong. For this reason, individuals should be allowed to make changes in the design of the interior and the immediate environment according to their needs, tastes, and personal preferences. When such flexibility is provided, individuals can make their living spaces more suitable for them and thus lead a more peaceful, comfortable, and healthy life.

Everyone perceives their environment uniquely, and the perceived environment may not always align with physical reality. A person's character, cultural background, and social experiences are crucial in shaping their interpretation of the environment. Consequently, the same environment may hold different meanings for individuals and can be described in different ways. Therefore, in the design of interior spaces and immediate surroundings, design decisions should prioritize enhancing the functionality and experiential quality of the space, independent of users' subjective perceptions. The designer must meticulously analyze user needs, environmental factors, and spatial relationships to create a space where these elements are harmoniously integrated.

Conclusion

This study aims to identify the prominent trends, research gaps, and potential future directions in the literature on the interaction between space and environment, utilizing bibliometric analyses and literature reviews. The findings provide a comprehensive evaluation of how this field has evolved, highlighting interdisciplinary approaches and the most frequently cited themes.

As a result of the bibliometric analysis, concepts such as attachment, identity, and spatial perception have emerged as central themes in the research on space and environment. Accordingly, future design practices are encouraged to incorporate customizable spatial solutions that enhance individuals' sense of belonging, integrate cultural identity through design details, and establish spatial hierarchies that improve user experiences.

By revealing the structural interconnectedness of key themes like attachment, identity, and place within a bibliometric network, this study offers an empirical foundation for rethinking interior design not simply as a functional endeavour, but as a culturally embedded, user-responsive practice.

Future research should expand upon these findings by employing mixed method approaches that combine bibliometric mapping with in-depth qualitative case studies, particularly focusing on underexplored user groups, cultural contexts, or adaptive reuse of interior environments. Additionally, examining how digital and virtual interiors (e.g., hybrid workspaces or immersive environments) affect spatial identity represents valuable new directions.

The thematic trends revealed in this study offer practical guidance for architects and interior designers aiming to develop user-centered, adaptable, and culturally responsive spatial solutions. These findings can support design professionals in creating environments that are not only functional but also meaningful and inclusive, ultimately contributing to enhanced user well-being and satisfaction.

The environment, much like human beings, is subject to continual change and development. The dynamic interaction between humans and their environments plays a decisive factor that shapes how interior spaces are perceived, used, and designed. Interior space thus becomes a tangible reflection of this relationship. Designers respond to these evolving interactions by producing spatial solutions that are sensitive to the diverse and changing needs of users. In this process, the individual is positioned at the center, with scientific data serving as a guide for achieving effective, evidence-based outcomes.

Understanding the human-environment relationship necessitates an in-depth examination of how individuals interact with their surroundings. Interior spaces are not merely physical containers defined by walls and boundaries, but holistic environments where social, psychological, and emotional dimensions converge. In these spaces, people form their identities and express their lived experiences. Therefore, interior design must go beyond the physical configuration and incorporate the psychological and sociological dynamics of users.

In conclusion, this research not only maps where the field has been but also illuminates where it must go—toward more integrated, data-informed, and human-centered approaches to space and environment design.

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Análisis de sustentabilidad del sistema turístico en la comunidad El Capulín, Reserva de la Biosfera Mariposa Monarca

Sustainability analysis of the tourism system in El Capulín community, Monarch Butterfly Biosphere Reserve

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Resumen

La construcción de indicadores permite detectar puntos críticos del sistema analizado, para detectar causas y dar soluciones, en el área turística los indicadores son limitados, aunque su aplicación ayuda a cuantificar el funcionamiento del destino y generar estrategias que beneficien a los involucrados. El objetivo de la presente investigación fue realizar un análisis de sustentabilidad de los productores en la comunidad El Capulín mediante indicadores en dimensiones; económica, social y ambiental con la finalidad de generar una línea base en el área sustentable, que sirva para un desarrollo rural, sustentado bajo el Marco para la Evaluación de Sistemas de Manejo de recursos naturales incorporando Indicadores de Sustentabilidad. Se diseñó una encuesta estructurada, referente a la actividad turística, aplicada con un muestreo intencional a 63 ejidatarios. El análisis estadístico genero seis indicadores en la dimensión económica, seis ambientales y diez sociales, la evaluación del sistema permitió conocer que el grupo PSTP tiene 65.03% de sustentabilidad, mientras que el grupo PSTM tienen 85.25%, la interacción en el sistema, arrojo que el turismo no

Abstract

The construction of indicators allows us to detect critical points of the analyzed system, to detect causes and provide solutions. In the tourism area, the indicators are limited, although their application helps to quantify the functioning of the destination and generate strategies that benefit those involved. The objective of this research was to carry out an analysis of the sustainability of producers in El Capulín community using indicators in dimensions; economic, social and environmental with the purpose of generating a baseline in the sustainable area, which serves for rural development, supported under the Framework for the Evaluation of Natural Resource Management Systems incorporating Sustainability Indicators. A structured survey was designed, referring to tourist activity, applied with intentional sampling to 63 ejidatarios. The statistical analysis generated six indicators in the economic dimension, six environmental and ten social, the evaluation of the system allowed us to know that the PSTP group has 65.03% sustainability, while the PSTM group has 85.25%, the interaction in the system showed that Tourism is not an economic activity that provides a good quality of life to those

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es una actividad económica que brinde una buena calidad de vida a los interesados, por ello, incrementar sus conocimientos como una estrategia para mejorar su desempeño y habilidades.

Palabras clave: Entorno social, trabajadores agrícolas, gestión ambiental.

interested, therefore, increase your knowledge as a strategy to improve your performance and skills.

Keywords: Social environment, agricultural workers, environmental management.

Introducción

El turismo es una actividad de repensar con miras al futuro desde el punto de vista más verde, inteligente e inclusivo, la industria turística mostro su importancia económica para los países, después de la crisis generada por el Coronavirus, las Naciones Unidas, recalcó la importancia de la industria para ser una vía de desarrollo sostenible para las comunidades rurales, las limitaciones que dejo la pandemia transformo a los turistas, ahora, su entorno económico es complicado, ajustando sus presupuestos, como en la selecciono de lugares cercanos a su residencia; las últimas cifras reportadas por la OMT el turismo internacional alcanzó el 97% de los nivel prepandémicos en el primer trimestre del 2024, el PIB directo del turismo recuperó los niveles previos a pandemia alcanzando un estimado de 3.3 billones de dólares (UNWTO, 2024a). El panorama económico de México se vio alterado y limitado en su crecimiento para el primer trimestre del 2022 (DATATUR, 2023). Sin embargo, la llegada de turistas internacionales durante enero del 2023 para México fue de 3,397200 turistas; mientras que, los ingresos de divisas referente al gasto total de visitantes internacionales ascendieron a 2,643.5 millones de dólares y el gasto medio por visitante fue por 445.9 dólares (INEGI, 2023).

El reciente crecimiento y recuperación del turismo internacional permite tomar acciones emergentes para visualizar a la actividad turística como un agente de transformación (UNWTO, 2022), las predicciones para México es que se consolidará como potencia turística, ya que se prioriza la captación de divisas y el gasto per cápita, por ello, visualizar y mejorar comunidades con asentamientos en zonas naturales es un reto para México y el mundo como lo señala los autores Loaiza-López et al. (2023), donde las Áreas Naturales Protegidas son una estrategia de conservación para la biodiversidad en el mundo, un agente importante dentro de estas zonas son las comunidades locales, volviéndose en un actor principal para la prestación de servicios turísticos como lo mencionan Chang & Wang (2023), donde, ellas deben identificar sus atributos turísticos y únicos para generar una buena experiencia a los visitantes, transmitiendo la preservación del entorno turístico para lograr un turismo sostenible.

Autores señalan que el turismo tiene impacto en el desarrollo sostenible, por su cooperación entre empresas, destinos y autoridades nacionales, regionales y locales, sin embargo, otros autores mencionan que la política de valorización de la naturaleza mediante el turismo no alcanza los objetivos establecidos en ciertos países como Argentina (Schenkel, 2024). Recientemente, estudios confirman que el turismo comunitario aporta a un desarrollo local y genera un crecimiento económico local mediante el aprovechamiento sostenible de los recursos, siendo una estrategia de reinvención para los destinos turísticos (Belupu Marchan et al., 2024; (Sánchez Piedra & Pachacama Calvopiña, 2023).

Nuevas corrientes de turismo demandan experiencias con calidad ambiental y contacto con las comunidades anfitrionas, cuando se realiza en ANP, su aprovechamiento turístico debe ser de bajo impacto y que proyecte un desarrollo armónico (Anzaldúa-Soulé et al., 2023). Otra actividad productiva dentro de las ANP es el agroturismo, su diseño contempla toda una cadena de valor para satisfacer a los visitantes, considerando todos los actores del sistema (Enríquez-Estrella et al., 2023). Las limitaciones de zonas alejadas y su vulnerabilidad por los ecosistemas que se presentan ellas, permiten que se revisen diferentes, modelos o estrategias para erradicar las malas prácticas, que pongan en riesgo las zonas naturales, por ello, se realizó la revisión de literatura en buscadores nacionales e internacionales como ELSEVIER, SCOPUS, REDALYC, DIALNET, entre otros, y se identificó que no hay trabajos relacionados con la zona de estudio referente a un análisis de sustentabilidad en la comunidad El Capulín, que sirvan como ejes para la generación de estrategias. Sin embargo, las diferentes investigaciones se enfocan en análisis desde la perspectiva natural, donde estás áreas presentan una gran complejidad como corredores biológicos (Martínez-Martínez et al., 2021; Vallejo et al., 2022).

Otras investigación realizadas en la zona, señalan que la generación de indicadores para medir el funcionamiento del ecosistema (fenología), en el área foliar (LAI: Leaf Area Index) mediante una serie en el tiempo de las diferentes coberturas (oyamel, pino, cultivos y arbustos) de la Reserva de la Biosfera de la Mariposa Monarca en un periodo de 2000 al 2015, sus resultados mostraron que la cobertura más abundante en la RBMM es el pino, con 216 pixeles, que corresponden al 37.43% de la zona de estudio (aproximadamente 20 000 ha), seguido por el oyamel con 183 pixeles (31.72%, cerca de 17 000 ha) y por último los arbustos, con 71 pixeles (12.31%, 6 500 ha) (España-Boquera et al., 2019). Por ello, la generación de indicadores en empresas forestales muestra como diferentes grupos tienen el aprovechamiento de los recursos naturales, cuyas prácticas de conservación permitirán el aprovecho a largo plazo de los recursos, mostrando que la zona de San Juan Xoconusco han tenido un deterioro mínimo por la actividad forestal (Rodríguez-Zúñiga et al., 2019).

Sin embargo, el énfasis de realzar análisis de sustentabilidad de la actividad turística en la zona permitirá contemplar el turismo como una estrategia que promueve la conservación ambiental para desarrollo socioeconómico como lo plantea Muñoz Barriga (2017). Hoy en día las estrategias del turismo son diversas, el aprovechamiento de la cultura permite que los visitantes puedan proteger o no al ambiente (Esfandiar et al., 2023). Por ello, el objetivo de la presente investigación fue realizar un análisis de sustentabilidad de los productores en la comunidad El Capulín mediante indicadores en dimensiones; económica, social y ambiental con la finalidad de generar una línea base en el área sustentable, que sirva para un desarrollo rural, sustentado bajo el Marco para la Evaluación de Sistemas de Manejo de recursos naturales incorporando Indicadores de Sustentabilidad.

El presente artículo está organizado de una introducción, en ella se muestra una revisión robusta del tema bajo estudio, posteriormente el marco teórico que proporciona elementos importantes para entender el sustento teórico del turismo y la sustentabilidad que respaldan el trabajo realizado, después, se presente el apartado metodológico con diferentes herramientas y técnicas para dar un sustento científico a la investigación, finalmente, el apartado de resultados y discusiones de los hallazgos encontrados comparados con otras investigaciones, para terminar con las conclusiones y referencias.

Marco Teórico

Sostenibilidad

Tras el retraso originario por el COVID-19, las naciones impulsan el complimiento de los objetivos del desarrollo sustentable entre ellos (fin de la pobreza, hambre cero, salud y bienestar, educación de calidad, igualdad de género, etc.), por ello, el desarrollo sostenible requiere de esfuerzos para construir un futuro inclusivo, sostenible y resiliente para las personas y el planeta (UNWTO, 2024b).En esas ideas el esfuerzo del Gobierno de México es forjar un futuro más justo, igualitario y sostenible, no dejando nadie atrás y nadie afuera (Gobierno de México, 2024). El poder apoyarse de estos conceptos como el desarrollo sustentable permite generar indicadores, utilizados como una estrategia de planificación y gestión que puede ser aplicada en sitios turísticos (Ocampo et al., 2018). En la revisión de literatura se identificaron diferentes métodos y técnicas utilizadas para la medición del impacto ambiental, como el Sistema para la Evaluación Ponderada del Impacto Ambiental de las Actividades Rurales (APOIA-Novorural), utilizado estándares ambientales para realizar las mediciones del lugar (Rodrigues et al., 2010), mientras, que Márquez-Romero et al., (2016) realizan la evaluación comparando los agroecosistemas, monitoreando en el tiempo, mediante indicadores como los propuestos por Blandi et al. (2015); Hernández & Martínez, (2024).

En el área de turismo la aplicación de la técnica Delphi, genera indicadores para el desarrollo de turismo comunitario, siendo puntos de origen para indicadores de confianza y futura toma de decisiones (Choi & Sirakaya, 2006). Por otro lado para obtener índices de sostenibilidad los autores Blancas et al. (2011) proponen la combinación de análisis de componentes principales y la distancia a un punto de referencia, donde, en turismo permite la comparación y caracterización de destinos, definiendo, comparando y cuantificando los objetivos propuestos, otra forma de medir la sustentabilidad es con el ISOST Index, herramienta utilizada en lugares turísticos, la cual identifica, normaliza y pondera el nivel de sustentabilidad contemplando el contexto del lugar (Torres-Delgado & López-Palomaque, 2018). Autores como Zhang et al. (2015), emplean un método de evaluación dinámico no lineal para evaluar la sustentabilidad turística, la metodología se basa en la dinámica de sistemas y la red neuronal de propagación hacia atrás, los resultados

proporcionan información útil para el control dinámico y la gestión científica del futuro en el turismo sostenible, todas estas herramientas estratégicas para expresar la situación actual del sistema.

Turismo sustentable

La importancia del turismo de naturaleza radica en promover el aprovechamiento sustentable de los recursos, además de ser una alternativa de empleos, una estrategia para el desarrollo de comunidades y un medio para la difusión del patrimonio natural y cultural de México (SEMARNAT, 2018). Los autores Lara-Pulido et al. (2021). señalan que las ANP juegan un papel importante para la derrama económica y son un objetivo principal para la captación de turistas y sin ellos nunca sucedería El desarrollar el ecoturismo en Áreas Naturales Protegidas, permite valorar el ambiente e integrar a la comunidad, para que el turista quiera conocer sobre la biodiversidad del lugar (De Silva-Melo et al., 2018). De tal forma que la sustentabilidad construye cotidianamente con ayuda de la comunidad un desarrollo armónico y para lograrlo es necesario asegurar que todos los interesados estén dispuestos a participar en el proceso (Butler, 1999; Ortiz Espejel, 2018). Sin importar los esfuerzos realizados en la actividad turística los autores Vilchis-Chávez et al. (2023) señalan que es necesario reforzar la relación entre el ser humano y la naturaleza e incluso mejorar la integración de las comunidades y las estrategias turísticas. La aplicación de indicadores ambientales y socioeconómicos en zonas de producción permite describir, comparar y caracterizar los sistemas estudiados (Pérez-Vázquez et al., 2024).

Mediante indicadores se analiza la sustentabilidad de las zonas permitiendo generar un panorama de la situación actual de la zona de estudio y cuáles son las intervenciones que se requieren, incluso realizar comparaciones sustentables (Pecci Oviedo, 2023; Cobos Mora et al., 2023).

Los autores Fabbroni et al. (2020) señalan que, dentro del proceso del desarrollo, un elemento a considerar es el territorio, el cual se entiende como un agente de transformación, este enfoque, es el que posibilitara que la actividad turística sea realmente un agente de desarrollo, por ello, la cercanía de diferentes zonas a puntos turísticos permite que ellas alcancen un desarrollo local sostenible, generando oportunidades las comunidades locales sin afectar o alterar el patrimonio mundial. Existen alternativas y modelos para el desarrollo turístico, algunos orientados hacia el mercado y otros hacia la geografía, el territorio, la geología, a las comunidades o al patrimonio, sin olvidar la interacción de instituciones públicas y privadas quienes trabajaran mediante un bien colectivo para su propio bienestar (Muñoz-Bascuñan & Rodríguez-Gamarra, 2023). El reto de las investigaciones en el área de turismo es considerar un turismo sustentable, hay que abordar tres pilares conceptuales (desarrollo económico, sociocultural y protección ambiental), los planificadores de centros turísticos y los gobiernos de algunos países deben considerar el factor social y ambiental, incluso las empresas deben voltear a ver el pilar económico (Oyarzun Lillo & Taucare Taucare, 2018; Hutchins et al., 2019). En la actualidad existen pocos estudios de sostenibilidad que permitan mejorar el bienestar de los productores, con ayuda de indicadores se puede valuar para obtener resultados que orienten las acciones a seguir para lograr un desarrollo sustentable (Cobos Mora et al., 2023).

Metodología

Diseño de la investigación

La presente investigación es exploratoria y descriptiva con una metodología mixta integrando sistemáticamente métodos cuantitativos y cualitativos en el estudio con el fin de tener una visión más completa del fenómeno, estos métodos de investigación mixta enriquecen la investigación por tener una mayor amplitud, profundidad, diversidad, etc. El considerar una investigación cuantitativa permite justificar la necesidad, descubre los problemas, los relaciona y los cuantifica, mientras que la investigación cualitativa proporciona las bases para darle contenido, profundiza sobre las causas, caracteriza el funcionamiento. El realizar esta investigación descriptiva permite que se tomen decisiones, evaluar y elegir el mejor curso de acción para beneficio del sistema por otro lado la investigación exploratoria nos permitirá brindar información y comprensión referente al estudio (Malhotra, 2004; Chaves-Montero, 2018).

A) Contexto geográfico y socioeconómico

La investigación se realice en El Capulín, comunidad perteneciente a Donato Guerra, Estado de México, localizado en el oeste del Estado de México. Limita al norte: Villa de Allende, al sur: Valle de Bravo e Ixtapan del Oro y Zitácuaro, las coordenadas geográficas son; 19°24'07" Latitud Norte y 100°19'13"

Longitud Oeste (Figura 2). El clima es templado subhúmedo con lluvias en verano, 45.29 % del territorio presenta bosques de pino, encino, ocote, cedro, eucalipto, fresno, sauce llorón, aguacate, chirimoya, zapote blanco, ciruela y membrillo) (INAFED, 2019).

Figura 1. Ubicación de la comunidad El Capulín, Donato Guerra, México.
Fuente: INEGI. Marco Geoestadístico Municipal versión 2016. (2019)

B) Población objetivo

La población del ejido El Capulín es de 306 personas, el grado de marginación es alto con un rezago social medio (SEDESOL, 2010), el grupo de ejidatarios oscila entre 75 integrantes, para el cálculo del tamaño de la muestra se utilizó la ecuación por Malhotra (2004) cuando se conoce la población para estudios exploratorios (Ecuación 1), considerando: nivel de confianza del 95 % equivalente a un valor de Z=1.96, población estimada de 75 ejidatarios (N), error permitido del 5 % (e) y una probabilidad de p y q de 0.5, el tamaño de la muestra fue 63 ejidatarios para ser considerados en la investigación.

$$n = \frac{(1.96)^2(0.5)(0.5)(75)}{(75)(0.5)^2 + (1.96)^2(0.5)(0.5)} = 63\ ejidatarios\ (Ecuación\ 1)$$

C) Tipo de muestro y análisis estadístico de los datos

El tipo de muestro aplicado fue un aleatorio simple, cuando se conoce la población y no es demasiado grande, se asigna números a los sujetos a participar, mediante un método al azar se selecciona cada individuo hasta completar la muestra requerida (Hernández-Ávila & Carpio, 2019). En una de las reuniones mensuales se realizó el sorteo colocando en una tómbola papeles con el nombre de los productores para que se discriminara a la población y así obtener la muestra; el registro de los participantes se anotó en una tabla para tener un seguimiento correcto. El punto de muestreo para la aplicación de las encuestas fue en el salón ejidal de la comunidad El Capulín.

D) Tipificación de los productores

Para la recolección de la información y su interpretación de la actividad turística, se diseñó una encuesta estructurada con base a las dimensiones y atributos propuestos en la metodología MESMIS (Masera et al., 1999; Astier & Hollands, 2005; Priego-Castillo et al., 2009) con aproximadamente 80 preguntas abiertas, cerradas y mixtas. Se utilizaron variables cualitativas y cuantitativas para tener una interpretación con enfoque mixto en la investigación. La aplicación de la encuesta fue el último lunes de cada mes, durante los meses de agosto a diciembre del 2018. La información recolectada se procesó y organizó mediante una base de datos en Microsoft Excel 2016 para simplificar su manejo.

El primer análisis estadístico que se aplicó fue un análisis de componentes principales, es una herramienta estadística que permite reducir variables, estas nuevas variables o componentes, permiten explicar la mayor parte de la variación de las variables originales, además es una técnica descriptiva que permite observar la relación entre variables cuantitativas, ayuda a observar las posibles variables que están generando variabilidad de los datos, transformando variables originales en variables correlacionadas para facilitar la interpretación, este método descriptivo, permite obtener una representación con las nuevas variables, por ello, este análisis facilita y simplifica datos para la interpretación, lo anterior es posible porque frecuentemente la variabilidad de los datos se puede explicar con un número pequeño de componentes, aquí el investigador centra la atención en ellas para la descripción o la interpretación (Hernández-Rodríguez, 1998; Peña, 2002; Villarroel et al., 2003; González & Felpeto, 2006).

Posteriormente, se hizo un análisis de conglomerados, técnica de análisis multivariante corresponde a un método de clasificación automática, que busca agrupar los elementos de una muestra de grupo homogéneos, tomando en cuenta la similitud entre ellos para así concentrar los esfuerzos para mejorar el sistema analizado, basado en las características que poseen, permite clasificar encuestados, de tal forma que cada objeto es muy similar al que está en el conglomerado, respecto a algún criterio seleccionado por el investigador, por tal razón el análisis permite clasificar grupos en base a las variables observadas y aunque es considerado como descriptivo y no inferencial, siendo una técnica exploratoria para clasificar de acuerdo con una relación natural entre los objetos, y finalmente, centrarse en la similitud "media" dentro de los conglomerados (Peña, 2002; Pedroza & Dicovskyi, 2006; De La Hoz & López Polo, 2017).

Acto seguido, se usó estadística descriptiva para la actividad económica de los ejidatarios por cada grupo mediante el Statistical Analysis System (SAS, 2014). Se utilizó un análisis de conglomerados para establecer la tipología de la actividad económica, los modelos de agrupación jerárquica se crearon utilizando el método de distancia euclidiana para encontrar la distancia entre las observaciones, donde es importante demostrar si dos individuos con determinadas características (variables) se deben considerar cercanos o no, se complemente con el criterio de Ward, para optimizar la varianza mínima dentro de los grupos, buscando la mínima variabilidad de los conglomerados, este análisis permite integrar y caracterizar las observaciones dentro de cada grupo y luego obtener las medias y porcentajes de las variables estudiadas. El proceso de tipificación y todos los análisis estadísticos se realizaron en el Statistical Analysis System (Baíllo-Moreno & Chané-Chávez, 2008; Díaz-Monroy & Morales-Rivera, 2012; Cuadras, 2014; SAS, 2014).

El diseño de la encuesta, se efectuó mediante el diseño y la elaboración de cuestionarios y entrevistas a la comunidad, con el propósito de recabar información de diferentes variables enfocadas a la actividad productiva de los ejidatarios, las variables fueron cualitativas y cuantitativas para una fácil interpretación, la encuesta se dividió en tres apartados. A) Características generales; en ella se encuentran preguntas como edad, sexo, estado civil, ingresos, entre otros. B) Turismo; las variables permiten entender el sistema turístico que se práctica en la comunidad como (número de turistas que atienden, horario de jornada, ingresos, gastos y costos por mencionar algunos. Finalmente, C) Capacitación y organización; muestra información (cuantas veces ha recibido una capacitación, que temas están interesados en recibir asesoría, organización, objetivo de la asociación, si tienen un líder, entre otras, El diseño de la encuesta fue producto de las diferentes observaciones y acercamientos en la zona de estudio, el contacto con la comunidad y lideres ejidales, permitió que se lograrán diseñar preguntas cuyo producto final permitiera tomar decisiones para todos los involucrados, además, la encuesta estructurada, en su contenido, presentaba preguntas de profundización en la actividad económica y algunas de clarificación para la explicación de agentes participantes (Quise Pari & Sánchez Mamani, 2011).

Para alcanzar confiabilidad y validez del cuestionario aplicado los autores (LeCompte & Goetz, 1982) señalan que el investigador debe tener participación durante el desarrollo de la investigación de campo, para tener una visión global de las actividades que realiza el grupo bajo estudio. por ello, para la selección de variables y los indicadores del cuestionario, se consideró el contexto de los productores de la comunidad conociendo el desarrollo de la actividad turística que se presente en el parador turístico., también se debe identificar claramente a los participantes, en esta investigación al grupo ejidal de la comunidad El Capulín, fue seleccionado por una revisión exhaustiva de literatura y de acercamientos en la zona, las diferentes visitas de campo y los acercamientos con lideres ejidales sustentaron el padrón del grupo ejidal, quienes se utilizaron en el estudio (Martínez Miguélez, 2016).

E) Análisis de sustentabilidad

La evaluación de la sustentabilidad de cada grupo obtenido, se usó la metodología MESMIS (Masera et al., 1999; Astier & Hollands, 2005; Priego-Castillo et al., 2009), para evaluar la sustentabilidad de los sistemas de manejo de recursos naturales mediante indicadores.

Los autores Masera et al. (1999), identificaron a pilares sobre los cuales se lleva a cabo la evaluación de la sustentabilidad, y un conjunto de atributos que se deben considerar en sistema de manejo de recursos naturales, bajo una perspectiva sistémica (Productividad, estabilidad; confiabilidad; resiliencia, adaptabilidad, equidad y autodependencia). Por ello, se obtuvieron 15 indicadores mediante la metodología MESMIS (Tabla 1) en tres dimensiones (económica, ambiental y social) con los atributos de productividad, resiliencia y adaptabilidad, auto suficiencia, adaptabilidad, equidad y auto organización. El atributo de productividad pertenece a la dimensión económica y muestra como el sistema hace el uso de sus recursos para su beneficio. Por otro lado, los atributos de resiliencia, estabilidad y auto suficiente entran en la dimensión ambiental y estos muestran como el sistema puede por sí solo ser resiliente, pero al mismo tiempo brinda información de su estabilidad con el funcionamiento de todas sus partes; por ello, la parte de auto suficiencia arroja la capacidad de funcionamiento del sistema visto desde su funcionalidad con el uso de sus propios recursos.

En la dimensión social se encuentran los atributos de adaptabilidad, equidad y auto gestión, explican como el sistema es capaz de aprender y adaptarse a las nuevas condiciones que se generan por elementos externos, incluso permite identificar el control, la forma de respuesta del sistema y cuál es la participación de todos los agentes involucrados. En la revisión de literatura no se encontraron valores de referencia para ocuparlos como un eje de comparación para evaluar el sistema, por eso la necesidad de contar con valores propios productos de esta investigación con el objetivo de que sean una línea base para la toma de decisiones en la comunidad y que sea referente en futuras investigaciones.

Tabla 1.
Indicadores económicos, ambientales y sociales, valor de referencia y método de medición de la actividad turística en El Capulín, Donato Guerra, Estado de México

Dimensión	Atributo de sustentabilidad	Indicador	Formula	Valores de referencia
Económica	Productividad	Ingresos netos Turismo Relación beneficio costo turismo	Total de ingresos – Total de costos Total de ingresos / Total de costos	$2059.62 $15.76
Ambiental	Resiliencia y Estabilidad Auto suficiencia	Disponibilidad del agua Reforestación Plantación de árboles Hectáreas plantadas	Encuesta: Disposición del recurso conforme a los productores (%) Encuesta: Participación de los productores para reforestar (%) Encuesta: Número de árboles en promedio que plantan por cada grupo Encuesta: Número de hectáreas que en promedio plantan árboles	100% 100% 101.5 1
Social	Adaptabilidad	Trabajo familiar no remunerado (%) Contratación de personas externas (%)	Encuesta: Familiares que ayudan en el sistema de producción (%) Encuesta: Ejidatarios que contratan personas externas para sus actividades económicas (%)	37.4% 12.5%
	Equidad	Asesoría técnica recibida (%) Interesados en recibir asesoría técnica (%) Participación en la toma de decisiones	Encuesta: Productores que han tomado alguna asesoría técnica (%) Encuesta: Productores dispuestos a recibir asesoría técnica (%) Encuesta: Productores que participan en la toma de decisiones (%)	44.5% 100% 91%
	Auto organización	Nivel de alfabetización (%) Organización de productores (%) Capacidad financiera (%)	Encuesta: Ejidatarios que tienen nivel de alfabetización (%) Encuesta: Ejidatarios que pertenecen a la organización (%) Encuestas: Ejidatarios que tienen la capacidad de volver a invertir para sus actividades	67.5% 100% 100%

(Elaboración propia, 2022).

Resultados y discusión

Para la realización de los indicadores bajo la metodología MEMSIS, primero se definió el objeto de la evaluación, en este primer paso se debe identificar el sistema o los sistemas que se van a analizar, segundo; caracterizar el sistema, sin olvidar que está metodología propone que la evaluación de la sustentabilidad se compare con uno o más sistemas. Por ello, una de las limitaciones de la investigación se centra que, durante la revisión de literatura en las bases de datos nacionales o internacionales, no existen valores de referencia en el área de estudio, generando los indicadores mediante la técnica de recolección de datos, investigaciones de campo y con apoyo de la revisión de literatura, los valores servirán como referencia en investigaciones futuras. Estos indicadores se diseñaron y están respaldados por las propias características de la zona de estudio y de la comunidad analizada, la selección de los indicadores en esta presente investigación se basó en atributos de sustentabilidad, después, se definieron los puntos críticos del sistema analizado, dando paso a los diferentes criterios de diagnosticó o conocidos como dimensiones de evaluación (económico, social y ambiental), como último paso se analiza la lista de indicadores para seleccionar aquellos con los que se va a trabajar cuyas características sean (integradores, fáciles de medir y confiables). Los métodos para obtener el valor de los indicadores en las dimensiones ya mencionadas se basaron en los siguientes pasos; revisión de literatura, datos históricos, levantamiento de encuestas a los actores claves, entrevistas abiertas o semiestructuradas con productores y actores claves de la comunidad.

Tipificación de los productores

Para la tipificación de los productores se realizaron técnicas mixtas para el análisis de dato, primero se realizó un análisis de componentes principales, este mostró que las dos primeras componentes principales explican el 83.38 % de la variabilidad total; mientras que, la componente principal 1 explica solo el 53 % con valores propios de 2.15 y 1.18, respectivamente. Ellas están conformadas por los ingresos y relación costo beneficio, y por edad y costo total (Tabla 2), respectivamente.

El análisis de conglomerados clasifico en dos grupos a los ejidatarios que realizan actividades de turismo en el Capulín, los cuales se denominaron Prestadores turísticos con baja experiencia y Prestadores turísticos con mucha experiencia, la clasificación se basó, primero en el número de personas que los apoyan para realizar su actividad, considerando que cada ejidatario es una pequeña organización, en el área de servicios la clasificación se muestra: Micro empresas de 0 a 20 integrantes, pequeña empresa de 21 a 50 y mediana empresa de 51 a 100 colaboradores o integrantes, estas MYPIMES TURÍSTICAS se enfrentan a problemas como; formación desde casa y pocas habilidades empresariales, limitaciones en la capacidad de sus recursos humanos, desconocimiento del Mercado y falta de vinculación con la tecnología., el nombre se designó por los años dedicados a la actividad, en promedio el grupo PSTP tienen dedicados 33 años, mientras que el grupo dos PSTM tiene 50 años (SECTUR, 2004). Esto se observa en el dendograma (Figura 2).

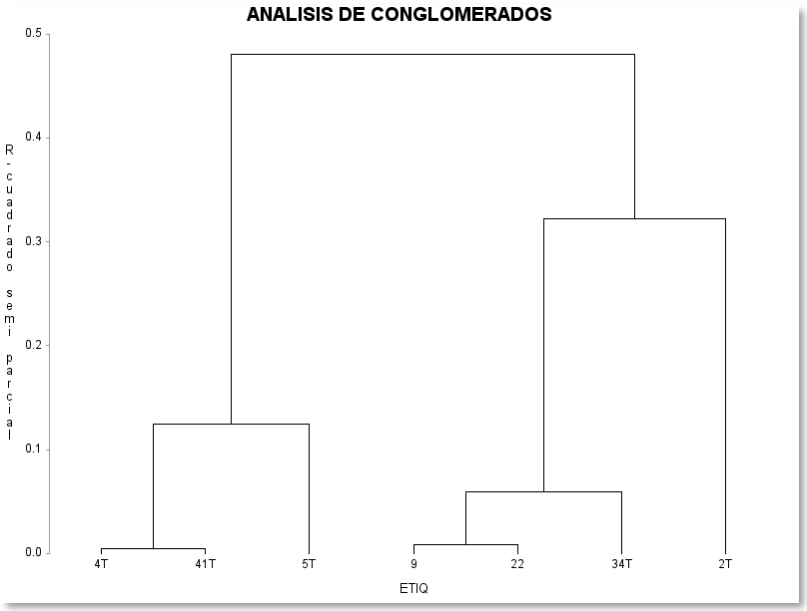

Figura 2. Agrupamiento de los prestadores de servicios turísticos en el Capulín, utilizando las dos componentes principales.
Fuente: elaboración propia con el análisis de datos del SAS (2014).

Tabla 2.
Valores propios de la componente principal uno y componente principal dos

Variable	Prestadores turísticos poca experiencia	Prestadores turísticos con mucha experiencia
EDAD	0.41	-.42
INGRESOS	0.65	0.22
COSTOS	0.18	0.85
RELACION BENEFICIO COSTO	0.60	-.21

Fuente: elaboración propia con el análisis de datos del SAS (2014).

El grupo uno Prestadores turísticos poca experiencia (PSTP) representan el 37.5% de los encuestados, referente al tema de los ingresos, encontramos que en promedio ganan $1186.66 pesos al mes, con una relación costo beneficio de 4.5 pesos, tienen edad promedio de 52 años y un costo total de $265.63 pesos para realizar su actividad. Sus edades son mínimas de 35 y máximo 40 años, 67% tienen escolaridad básica como primaria trunca y el 33% sin escolaridad, su capacidad de lectura y escritura es para llevar sus actividades cotidianas, sin embargo, en la intervención con los encuestados, no pudieron dar lectura de forma correcta. El 100% de ellos no presentan alguna discapacidad.

El grupo dos Prestadores turísticos con mucha experiencia (PSTM) está conformado por el 62% de los ejidatarios, con una edad mínima de 48 a 74 años, en comparación con el grupo PSTP se puede observar que tienen una edad mayor, indicando que tienen más tiempo dedicado a la actividad turística. Relacionado a la variable educación encontramos que el 80% no tienen escolaridad, mientras que el 20% tienen primaria trunca, valor similar al grupo PSTP, en temas de lectura y escritura lo pueden realizar y no presentan alguna discapacidad.

Generación de Indicadores de sustentabilidad

La investigación es la primera en generar indicadores de sustentabilidad en El Capulín; por ello, genera los valores de referencia, son una línea base para facilitar la toma de decisiones en la comunidad mediante el análisis de las dimensiones (económica, ambiental y social), de la actividad turística, las cuales se describen con ayuda de atributos como productividad, resiliencia, estabilidad, autosuficiencia, adaptabilidad, equidad y auto organización. Para la generación de indicadores es fundamental un valor de referencia y la falta de este, obliga a la presente investigación a calcular los indicadores con el porcentaje de respuestas de las encuestas aplicadas a los ejidatarios de la comunidad El Capulín. Finalmente, la generación de los indicadores se muestra a continuación, explicados en cada dimensión en la tabla 3.

a) Dimensión económica

El atributo de productividad fue seleccionado para ser el indicador más representativo en la dimisión económica, cuya información es proporcionar las acciones que dañan o benefician al sistema de producción en la comunidad, para medir el aprovechamiento de los recursos, se calculó el indicador (IN) Ingresos netos, el cual se obtuvo del total de ingresos (I) menos total de costos (C): (I – C = IN). El otro atributo fue la (RBC) Relación beneficio costo, se obtiene de dividir los ingresos netos entre los costos totales (RBC = I / C).

En el área de turismo el grupo PSTP tienen Ingresos Netos promedios (1186.66 – 265.63 pesos = $921), mientras que su Relación Beneficio Costo promedio es (1186.66 / 265.63 = 4.5. pesos). El grupo dos PSTM tienen Ingresos Netos promedios (3500 – 310.75 = 3189.25 pesos), mientras que su Relación Beneficio Costo promedio (3500 / 310.75 = 11.26 pesos) Tabla 3. La diferencia de los valores es que el grupo PSTP atiende un 77% de los turistas que seleccionan subir caminando, mientras que el 75% de los turistas atendidos por el grupo PSTM rentan caballos. Los rangos de propina para la primera componente es de 30 a 100 pesos, mientras que el otro grupo entre 20 a 100 pesos, en atención de turistas por fin de semana es los PSTP van entre 10 personas y los prestadores PSTM en promedio 9, la diferencia radica en que el primer grupo más del 77% su recorrido lo realizan caminando y el segundo usan caballos, ambos grupos destinan entre 7 a 8 horas para realizar el recorrido, también ambos no gastan en servicios de veterinario para el caballo, ni en agua o alimentos durante su jornada laboral.

Durante los meses de la mariposa monarca tanto el grupo PSTP y PSTM no venden los caballos ya que son utilizados en sus actividades agrícolas, se identificó que el 33% tienen un caballo y el otro 77% no cuentan con ellos, respecto a la componente PSTM, se muestra que 25% tiene un caballo, el otro 25% ninguno y en un 50% tienen un caballo, mostrando así una diferencia significativa del ingreso en cada integrante de la componente. Referente a los ingresos mensuales por temporada o gastos totales que se presentan en la actividad del fenómeno migratorio de la mariposa monarca, se muestra que el 100% no contabilizan o registran sus ingresos en ambas componentes, situación que se presenta también en el grupo PSTP, mostrando dificultades para poder identificar o no la aportación real de la actividad turística.

Tabla 3.
Valores agrupados de los indicadores en la dimensión económica, utilizados en el análisis MESMI de la actividad turística en la comunidad El Capulín, Estado de México

Dimensión	Indicador	Fórmula	Valores PSTP	Valores PSTM
Económica	Ingresos netos turísticos	Total de ingresos turísticos – Total de costos	$921	$3198.25
	Relación beneficio costo	Total de ingresos turísticos / Total de costos	$4.5	$11.26

Fuente: elaboración propia con el análisis de datos del SAS (2014).

b) Dimensión ambiental

Para la generación de indicadores en el área ambiental, no se encontraron valores de referencia, por ello, se generó mediante las encuestas aplicadas. El indicador "Disponibilidad de agua" se calculó con la cantidad de respuestas que afirmaron que tienen disposición del recurso teniendo un valor de 100% en ambos grupos. En el indicador "Reforestación" se calculó de las encuestas, donde los ejidatarios decían si participaban en la reforestación, teniendo un valor de 100% para los dos grupos, mientras que en el indicador "Plantación de árboles" también se generó con ayuda de las encuestas, mostrando diferencias significativas, el grupo uno PSTP en promedio plantan 106 árboles anuales, aunque el grupo dos PSTM siembran en promedio 100 árboles al año, plantado ambos grupos una hectárea, valor calculado con sus respuestas (Tabla 4).

Tabla 4.
Valores agrupados de los indicadores en la dimensión ambiental, utilizados en el análisis MESMI de la actividad turística en la comunidad El Capulín, Estado de México

Dimensión	Indicador	Fórmula	Valores PSTP	Valores PSTM
Medio ambiente	Disponibilidad del agua	Encuesta: Disposición del recurso conforme a los productores (%)	100%	100%
	Reforestación	Encuesta: Participación de los productores para reforestar (%)	100%	100%
	Plantación de árboles	Encuesta: Número de árboles en promedio que plantan por cada grupo	106	100
	Hectáreas plantadas	Encuesta: Número de árboles en promedio que plantan por cada grupo	1	1

Fuente: elaboración propia con el análisis de datos del SAS (2014).

c) Dimensión social

La generación de los indicadores fue mediante la interpretación de las encuestas, en la revisión de literatura no se encontró un valor y se muestra el comportamiento de la primera componente llamada Prestadores de Servicios Turísticos con Poca Experiencia (PSTP), expresan que utilizan en un 35% a sus familiares para dar el recorrido turístico y en un 5% ellos contratan a personas externas para brindar este servicio cada temporada. En el tema de educación se muestra como la actividad turística presenta grandes dificultades en ese sentido; arrojo que el 66% tienen una escolaridad, aunque el nivel de educación es básico logrando en

promedio la primaria, en el nivel de lectura y escritura el 94% saben hacerlo, sin embargo, la interacción con el grupo, se logró identificar que son habilidades muy débiles lo cual es un riesgo e incertidumbre al bajar información para el grupo ejidal y ellos acepten realizarlas.

En la capacitación la componente PSTP han recibido alguna capacitación en un 29%, mientras que el grupo PSTM tienen un valor del 60%, esta es una arista de oportunidad para tomar acciones que beneficien a los ejidatarios, la disposición de los involucrados es viable, en donde el 100% de los integrantes de las componentes están interesados en recibir asesoría técnica, especialmente en temas (atención al turista, idiomas y agricultura como producción de aguacate y maíz). En la descripción de la información se encontró que los PSTP podrían recibir la capacitación en domingo en un 66.6% a diferencia del grupo PSTM que en un 50%, información que sirve como un eje para la gestión de los cursos de capacitación en la comunidad es que estarían interesados en recibir en promedio dos horas de capacitación entre las 12 am a las 16:00 pm. Analizando la información del trabajo de campo se ve la participación de instituciones como la *World Wiled Found* (WWF) y el Fondo Monarca, quienes apoyan y están en contacto con los involucrados, entre los temas de capacitación que en algún momento brindaron a los ejidatarios, se encuentran Trato al turista e información general del fenómeno migratorio de la mariposa monarca, sin ningún costo y aportaron habilidades y conocimientos para el desempeño de su actividad.

El indicador en la participación en la toma de decisiones permitió observar que el grupo tiene una participación del 82%, identificando que la participación si tiene relevancia, aunque están presentes en la toma de decisiones, y aunque el 100% pertenecen a la organización, no todos están involucrados en las decisiones como se mostró en el indicador anterior, 66.6% conocen el objetivo de que consiste en atender temas del ejido, mientras que el 33% no, este grupo mención que existen aproximadamente 220 integrantes, el 100% saben que tienen un líder o representante ejidal, quien mensualmente da reporte a los ejidatarios. Finalmente, el indicador Capacidad financiera muestra que el aprovechamiento del fenómeno de la mariposa monarca es consecutivo y año con año, pueden aprovechar los recursos para brindar el servicio, aunque en la interacción con ellos, también, señalaron la disminución de las mariposas, por ello, es importante considerar el gestionar, atender y generar estrategias para preservar el fenómeno (Tabla 5).

Tabla 5.
Valores agrupados de los indicadores en la dimensión social, utilizados en el análisis MESMI de la actividad turística en la comunidad El Capulín, Estado de México

Dimensión	Indicador	Fórmula	Valores PSTP	Valores PSTM
Social	Trabajo familiar no remunerado (%)	Encuesta: Familiares que ayudan en la actividad turística (%)	35%	40%
	Contratación de personas externas (%)	Encuesta: Ejidatarios que contratan personas externas para su actividad turística (%)	5%	20%
	Asesoría técnica recibida (%)	Encuesta: Productores que han tomado alguna asesoría técnica (%)	29%	60%
	Interesados en recibir Asesoría técnica recibida (%)	Encuesta: Productores dispuestos a recibir asesoría técnica (%)	100%	100%
	Participación en la toma de decisiones	Encuesta: Productores que participan en la toma de decisiones (%)	82%	100%
	Nivel de escolaridad (%)	Encuesta: Ejidatarios que tienen escolaridad (%)	60%	75%
	Nivel de lectura y escritura (%)	Encuesta_ Ejidatarios que saben leer y escribir (%)	100%	100%
	Organización de productores (%)	Encuesta: Ejidatarios que pertenecen a la organización (%)	100%	100%
	Capacidad financiera (%)	Encuestas: Ejidatarios que tienen la capacidad de volver a invertir para sus actividades (%)	100%	100%

Fuente: elaboración propia con el análisis de datos del SAS (2014).

Por otro lado, el grupo Prestadores de Servicios Turísticos con Mucha Experiencia (PSTM) recurren a un 40% de sus familiares para su actividad, esto gracias a que cuentan con caballos para poder ofrecer recorridos donde los hijos son un recurso humano importante, con un 5% mayor al grupo anterior, en la contratación personas externas para sus actividades lo realizan en 20%, con una diferencia de 15% a PSTP. En la escolaridad encontramos que los ejidatarios tienen un 50% de escolaridad, aunque sus niveles de estudios llegan a secundaria, esto permite que la interacción y comunicación con ellos podría ser fluida y alcanzar acuerdos a favor del sistema y de los involucrados, aunque tiene 16% menor de escolaridad que PSTP, la desigualdad se presenta por el grado de educación un poco más grande, en el indicador de nivel lectura y escritura se muestra en la Tabla 7, que 75% de ellos si pueden realizarlo, en este grupo se logró ver las habilidades relacionadas con este indicador y aunque están por debajo de un 19% a PSTP.

La capacidad de cambio en sistemas como la comunidad El Capulín son evidentes y necesarios para su evolución y supervivencia, donde estrategias y propuestas pueden formar parte del cambio, como los indicadores de Asesoría técnica recibida, Interesados en recibir asesoría técnica, Organización de productores y Participación en la toma de decisiones. En la Organización de productores los PSTP muestra un 94% de organización, quienes participan, se involucran, asisten, forman parte y trabajan a favor del ejido. En la participación en la toma de decisiones un 82% son integrantes y agentes activos para elegir a sus representantes, también, asisten a las asambleas para llegar acuerdos. En el área de Asesoría Técnica muestran que un 29% han tomado alguna asesoría, siendo un punto de trabajo a futuro para mejorar sus prácticas, una bondad del sistema es que 100% de ellos están interesados en recibir asesoría técnica. La capacidad financiera es similar a la componente anterior también tiene la facilidad de volver a realizar la actividad año con año, gracias a la disponibilidad de los recursos para poder aprovechar cada temporada.

d) Evaluación de la sustentabilidad

Para el análisis de sustentabilidad de la actividad turística se realizó una técnica mixta para la interpretación de los resultados, se realizó un diagrama AMOEBA o radiales (Figura 3), el cual muestra la representación gráfica del análisis de sustentabilidad de los indicadores obtenidos, correspondientes del análisis de conglomerados y se puede ver en correspondencia con los resultados explicados anteriormente que los grupos muestran diferencias significativas la escala utilizada en la presente investigación se representa (cero como el valor más bajo, 10 como el valor más alto y el cinco el valor de referencia), esta expresa de forma clara.

En la dimensión económica los indicadores que se obtuvieron de la recolección de los datos fueron (Ingresos netos y Relación beneficio costo), en la revisión de literatura no se encontraron valores de referencia de la comunidad, por ello, para calcular este valor se sacó un promedio, se puede observar que el grupo denominado Prestadores de Servicios turísticos con Mucha Experiencia (PSTM) se encuentra por encima del grupo Prestadores de Servicios Turísticos con Poca Experiencia, sin embargo, estos valores no llegan a un valor optimo. En concordancia con los autores Ontiveros et al. (2015) uno de los factores externos que limitan al sistema es el Gasto turístico donde al igual que en el parador El Rosario en el Estado de Michoacán existen variaciones en la llegada de turistas y por consiguiente en su derrama económica, en relación a ello, el gasto promedio por día oscila entre 1530 y 250 pesos entre el 2003 y la temporada 2013-2014 desde el reporte por los autores, mientras que en el Capulín el gasto promedio es de $250 pesos para el grupo PSTP y en el grupo PSTM sus ingresos son $850 pesos, por fin de semana considerando que los días con mayor afluencia es viernes, sábado y domingo.

Para definir la dimensión área ambiental con los atributos resiliencia y estabilidad se generaron los indicadores (Disponibilidad de Agua, Reforestación, Plantación de Árboles y Hectáreas plantadas), se puede observar en la figura 3, que ambos grupos están en el valor de referencia e incluso el grupo PSTP tiene un valor de 5.15 en el indicador plantación de árboles, el nivel de conciencia ambiental se muestra dentro de los grupos, aunque, se calculó mediante las encuestas los valores de referencia ya que no se encontró un valor.

Figura 3. Análisis de sustentabilidad de la actividad turística en la comunidad El Capulín, Estado de México.
Fuente: Elaboración propia, 2023.

Para la interpretación de la dimensión social se utilizó el atributo de adaptabilidad con indicadores (Trabajo familiar no remunerado y Contratación de personas externas) y aunque en la figura 3, el indicador trabajo familiar se encuentra en similitud con el valor de referencia, mismo que fue calculado con los datos se las encuestas, el indicador Contratación de personas externar muestra diferencias significativas ya que el grupo PSTP tiene un valor de 2, mostrando que su actividad de producción agrícola no es indispensable para la contratación mientras que el grupo PSTM por la producción que tiene, si se ven obligados a contratar personas durante el ciclo agrícola. Con la ayuda del atributo de Equidad se expresa que el grupo PSTM está por arriba del valor de referencia en los indicadores de Asesoría técnica e Interesados en recibir asesoría técnica, mientras que el grupo PSTP está por debajo del valor de referencia, valores importantes para gestionar las acciones de mejora en el diseño de cursos de capacitación para la comunidad, cuyo objetivo sea el mejorar sus prácticas empíricas de sus actividades económicas, para incrementar sus conocimientos y volverlos autosuficientes en la mejor de sus actividades.

En el área de auto organización se muestra el sistema en los niveles del valor de referencia, especialmente en los indicadores Participación en la toma de decisiones y en Organización de productores, lo mismo sucede en el Nivel de escolaridad y el Nivel de lectura y escritura, siendo estos una ventaja para la organización y desarrollo de los temas que se podrán impartir en la comunidad como estrategias a corto plazo. El indicador Organización de productores presenta para ambos grupos un valor del 100% la necesidad de este indicador es relevante ya que muestra y sirve como una vía de comunicación entre la comunidad y las instituciones públicas o privadas para la gestión armónica de la reserva. Finalmente, la capacidad financiera en el área turística esta muestra diferencias muy relevantes, ya que el grupo PSTP muestra un riesgo para la continuidad de sus actividades mientras que el grupo PSTM no tienen un valor optimo, pero si tendrá la capacidad a futuro de poder continuar con sus actividades. Por ello, es relevante la toma de decisiones para mejorar sus practicas, mediante el desarrollo de cursos de capacitación e incluso

seleccionar actores muestras que participen en la mejora para su implementación y evaluación de las estrategias.

Los resultados anteriores se respaldan de la siguiente información el grupo PSTP explica que el 66.6% de sus miembros si están organizados mientras que el 33% no, el objetivo de la organiza. La componente PSTM tiene un 100% de participación por parte sus miembros, pero no tienen contacto con alguna institución ya que es una de las responsabilidades de su líder, aunque ellos identifican a la Comisión Nacional de Áreas Naturales Protegidas y a la cabecera municipal como principales agentes de comunicación. Finalmente, el 100% de los encuestados tienen un dato aproximado de los integrantes que oscilan entre 260 personas. En la toma de decisiones o en la gestión de responsabilidades el 100% asevera que se delegan responsabilidades, y que se tiene un líder, este es seleccionado mientras votaciones por todos los integrantes de la organización.

Acciones de mejora

De acuerdo con el autor para tener una capacitación que, de resultados, debe ser aquella que perfecciona el desempeño, pero mediante la identificación de las necesidades se deben jerarquizar y priorizar para tener una prioridad en la capacitación, por ello, mediante el análisis de los resultados y la evaluación de la sustentabilidad del sistema turístico se propone acciones de mejora en el área de turismo y agricultura para mejorar el conocimiento en sus actividades.

La gestión con el líder sindical para que se brinde un curso de como atender al turista para los ejidatarios que prestan servicios durante la temporada de la mariposa monarca, viendo el área de propinas como un incremento a sus ingresos desde su actitud servicial. En el área agrícola transformar su agricultura de auto consumo en una que permita obtener ingresos relevantes para mejorar sus condiciones, la participación con expertos en el área de producción de aguacate y maíz, cuya finalidad sea corregir errores empíricos en el ciclo de producción de maíz para incorporar nuevas prácticas que mejoren al sistema.

Discusión

En zonas rurales y en otras partes del mundo, el turismo es un motor de desarrollo económico, sin embargo, es un recurso alternativo a sus diferentes fuentes de ingresos como la actividad agrícola, en concordancia con los autores (Juárez et al., 2024), el turismo contribuye a la generación de ingresos, aunque es mínima su contribución al desarrollo de las comunidades como en El Capulín. Algunas comunidades para hacer frente a condiciones limitadas en las que se encuentran, especialmente los campesinos, productores o prestadores de servicios turísticos, realizan diferentes estrategias de diversificación para incrementar sus ingresos o incluso más fuentes, por ello, el turismo realizado en la zona se vuelve una economía circular pero complementaria de la zona (Tamayo Ortiz et al., 2023).

La presente investigación permite mostrar como los sistemas turísticos desarrollados en Áreas Naturales Protegidas como la comunidad El Capulín perteneciente a la Reserva de la Biosfera de la Mariposa Monarca y que a pesar de que la mayor parte de las riquezas naturales y culturales de México se encuentran en las zonas rurales, es en ellas donde se concentran los mayores índices de pobreza y rezago social, mencionado en Programas para el Bienestar (SEGOB, 2023). En similitud con Brenner & Job (2006) el impacto económico de la actividad turística en la región es mínima e incluso en comparación con otras Áreas Naturales Protegidas, por ello, es indispensable la aplicación de cursos de capacitación para mejorar sus conocimientos y lograr incrementar sus ingresos mediante la mejora de sus actividades económicas para que se perfeccionen y minimicen errores, volviéndose no solo de supervivencia sino de un estilo de vida mejor.

En concordancia con los autores Martínez et al., (2008) es un desafío que el sistema tenga innovación, este nivel debe lograrse poniendo atención a la capacitación o asesoría técnica, proponiendo como una acción de mejora incrementar los conocimientos de ejidatarios en la actividad turística mediante cursos de atención a clientes y asesoría agrícola para que sus prácticas empíricas mejoren con el incremento de conocimientos., un elemento importante para ser presentado con actores en especial en el área pública, es la importancia de la responsabilidad social empresarial, ya que es en nuestro país un escenario para que las organizaciones tomen conciencia sobre conductas relacionadas a la Responsabilidad Social beneficiando a las comunidades, una inversión en el municipio o en la comunidad daría un valor agregado a su economía (Bonilla-Cruz & Cobian-Romero, 2019).

Conforme a la literatura se encontró que las instituciones involucradas suman esfuerzos mediante diferentes incentivos, como económicos, para recuperar y conservar las zonas de hibernación de la Mariposa Monarca cada año, en concordancia con los autores Dominguez-Hernandez et al., (2018), quienes mencionan que estudios de este tipo permiten identificar el nivel de integración que tienen productores, mediante un análisis de componentes principales. Por ello, se encuentra que en otros ejidos también se realizan campañas de reforestación ya sea del Estado de Michoacán o Estado de México (WWF, 2018), la donación de los árboles es la mejor herramienta para la participación de los ejidos. Para brindar a los visitantes una experiencia placentera teniendo en cuenta la gestión comunitaria, reducir los impactos negativos del turismo y mejorar la calidad del turismo, es necesario aclarar la relación entre el valor de la experiencia del turismo comunitario y las acciones de gestión de visitantes conforme a los autores Chang & Wang (2023), voltear a ver a la comunidad como un agente de transformación pero que su participación sea más del 100% en sus propias actividades, en la generación de estrategias y en la aplicación y seguimiento de ellas, la presente investigación permite que otros estudios, utilicen los indicadores generados como un valor de referente por la falta de información.

Conclusiones

La tipificación de los ejidatarios de la comunidad El Capulín permitió obtener dos grupos en la actividad turística, denominados como Prestadores de servicios turísticos con poca experiencia (PSTP) y Prestadores de servicios turísticos con mucha experiencia (PSTM) para la primera actividad, mientras que a la segunda se denominaron Productores de aguacate y Productores de Maíz quienes no tuvieron mismos valores en los indicadores obtenidos. El usar indicadores de la metodología MESMIS a los ejidatarios de la comunidad El Capulín permitió evaluar diferentes dimensiones (social, económica y medio ambiental), también sus relaciones que afectan o beneficien al sistema, para evaluar las diferentes dimensiones fue necesario construir indicadores que se puedan medir mediante una escala cuantitativa o cualitativa usando un valor de referencia o generando los propios valores para describir a detalle los indicadores y sus valores. Los resultados de la investigación permitieron obtener 6 indicadores en la dimensión económica, 6 en la parte ambiental y 10 en la parte social.

La evaluación de sustentabilidad arrojo datos duros respecto a la situación actual del sistema, donde, el grupo PSTP tiene un porcentaje de un 65.03%, mostrando sus limitantes y vías de mejora respecto al grupo dos PSTM, cuya sustentabilidad es de 85.25%, estos valores son una línea base para la comunidad ya que no se encontró un valor similar, el utilizar indicadores permitió detectar de manera simple, clara y objetiva algunos puntos críticos del sistema de producción incluso para y proponer soluciones de mejora con la ayuda de cursos de capacitación para el trabajo en el área de turismo de los ejidatarios de la comunidad El Capulín. Los indicadores para el grupo PSTP en la dimensión social como Trabajo familiar no remunerado, Contratación de personas externas, Nivel de escolaridad, Nivel de lectura y escritura, Capacidad financiera y autosuficiencia, demuestran que es un sistema frágil y en constante amenaza por la misma inestabilidad que presenta, con ayuda de la mejora de sus conocimientos esta vía de trabajo permitiría una resiliencia al sistema.

Finalmente, los resultados se vuelven una línea base para la medición de la sustentabilidad en los sistemas con actividades turísticas, para crear modelos que sirvan como una guía para el mejoramiento de otros sistemas con las mismas características, la medición de los resultados se logró mediante un análisis cuantitativo y cualitativo por la complejidad del sistema y es evidente que los ejidatarios de la comunidad presentan una productividad y estabilidad incierta por su operación empírica de las actividades, sin embargo, se logró observar que en los grupos PTSM y Productores de aguacate que realizan prácticas distintas que les permite tener un ingreso extra a su economía, la investigación permite mostrar la necesidad de mejorar el sistema con los valores obtenidos de las técnicas mixtas aplicadas a la investigación, el mejorar los sistemas de producción son un reto, cuya complejidad se presente en la generación de datos y la falta de valores para realizar comparaciones con otros sistemas de producción.

Trabajos futuros

Los resultados de la presente investigación sirven como una línea base para áreas con similares características. La generación de los indicadores son una evidencia de los trabajos futuros que se requieren en la comunidad El Capulín, así también muestra la necesidad de tener integración de diferentes actores del sistema para lograr el beneficio integral de la comunidad.

El análisis realizado permite ver la capacitación como una alternativa para mejorar las prácticas en las actividades económicas de la comunidad. No obstante, es un reto involucrar a los productores para ver el incremento de sus conocimientos como una alternativa de desarrollo. Por último, se plantea ver el tema agrícola como una actividad económica importante y no de auto consumo, las mejoras en su producción resultarían beneficiarias para la comunidad quienes apuestan por la producción de aguacate a largo plazo.

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Epiisopiloturin–Hydroxypropyl-β-Cyclodextrin inclusion complexes: preparation, characterization, and application in neglected diseases

Complexos de inclusão de epiisopiloturina-hidroxipropil-β-ciclodextrina: preparação, caracterização e aplicação em doenças negligenciadas

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Abstract

Context: *Pilocarpus microphyllus* (Jaborandi) is widely used for extracting pilocarpine, generating biomass rich in secondary metabolites. Among these, epiisopiloturin (EPI) exhibits potential against neglected diseases, in addition to anti-inflammatory and antinociceptive effects. However, its poor aqueous solubility limits its pharmaceutical application. **Objective:** To enhance the solubility of EPI by forming an inclusion complex with hydroxypropyl-β-cyclodextrin (HPβCD) using the freeze-drying technique. **Methods:** A phase solubility study was conducted to determine the stability constant and stoichiometry. The inclusion complex was prepared via lyophilization and characterized by Differential Scanning Calorimetry (DSC), Fourier Transform Infrared Spectroscopy (FTIR), X-ray

Resumo

Contexto: *Pilocarpus microphyllus* (Jaborandi) é amplamente utilizado para extrair pilocarpina, gerando biomassa rica em metabólitos secundários. Entre eles, a epiisopiloturina (EPI) apresenta potencial contra doenças negligenciadas, além de efeitos anti-inflamatórios e antinociceptivos. No entanto, sua baixa solubilidade em água limita sua aplicação farmacêutica. **Objetivo:** Aumentar a solubilidade da EPI através da formação de um complexo de inclusão com hidroxipropil-β-ciclodextrina (HPβCD) utilizando a técnica de liofilização. **Métodos:** Foi realizado um estudo de solubilidade de fase para determinar a constante de estabilidade e a estequiometria. O complexo de inclusão foi preparado por liofilização e caracterizado por calorimetria diferencial de varredura (DSC), espectroscopia de infravermelho

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Diffraction (XRD), and in vitro dissolution testing. **Results:** Characterization confirmed the formation of the EPI:HPβCD complex, indicating strong interactions between components. The DSC thermogram showed the disappearance of the EPI melting peak, supported by FTIR results, suggesting successful complexation. XRD patterns revealed an amorphous structure. In vitro dissolution demonstrated a marked increase in solubility: 100% of the complexed EPI dissolved within 5 minutes, compared to only 19% of the free compound. **Conclusion:** Complexation with HPβCD significantly improved the solubility of EPI, reinforcing its potential for development into an innovative pharmaceutical formulation for the treatment of neglected diseases.

Keywords: Epiisopiloturin, Cyclodextrin, Inclusion complex, Increased solubility.

por transformada de Fourier (FTIR), difração de raios X (XRD) e testes de dissolução in vitro. **Resultados:** A caracterização confirmou a formação do complexo EPI:HPβCD, indicando fortes interações entre os componentes. O termograma DSC mostrou o desaparecimento do pico de fusão do EPI, apoiado pelos resultados da FTIR, sugerindo uma complexação bem-sucedida. Os padrões de XRD revelaram uma estrutura amorfa. A dissolução in vitro demonstrou um aumento acentuado na solubilidade: 100% do EPI complexado se dissolveu em 5 minutos, em comparação com apenas 19% do composto livre. **Conclusão:** A complexação com HPβCD melhorou significativamente a solubilidade do EPI, reforçando seu potencial para o desenvolvimento de uma formulação farmacêutica inovadora para o tratamento de doenças negligenciadas.

Palavras-chave: Epiisopiloturina, Ciclodextrina, Complexo de incluso, Maior solubilidade.

Introduction

Neglected tropical diseases (NTDs) predominantly affect low-income populations and receive limited investment from the pharmaceutical industry (Dias et al., 2013). It is estimated that they contribute to approximately 12% of the global disease burden, causing more than 35,000 deaths daily, mainly in developing countries (Conteh et al., 2010). Despite this, less than 5% of global R&D funding targets therapies for NTDs (Chatelain & Ioset, 2011).

Consequently, affected populations lack adequate treatments and suffer from limited therapeutic options. Effective drug access is therefore crucial for addressing these public health issues (Venturini et al., 2008). *Pilocarpus microphyllus* (Jaborandi) contains various alkaloids of pharmaceutical interest. Among them, pilocarpine (PILO) and epiisopiloturin (EPI) demonstrate biological activities, particularly against parasites responsible for schistosomiasis (Veras et al., 2012; Véras et al., 2013), with some results surpassing praziquantel (PZQ), the reference drug. Additionally, EPI exhibits activity against *Leishmania spp*. (Guimarães, 2018) and anti-inflammatory effects.

However, the poor water solubility and low oral bioavailability of EPI limit its therapeutic application (Veras et al., 2012). Cyclodextrins (CDs), cyclic oligosaccharides capable of forming inclusion complexes with lipophilic molecules, are a well-established strategy to enhance solubility and dissolution rates of poorly soluble drugs (Del Valle, 2004; Sarabia-Vallejo et al., 2023).

Different techniques, such as freeze-drying, spray-drying, and co-precipitation, can be used to prepare inclusion complexes. Freeze-drying is particularly advantageous, producing amorphous powders with strong drug-CD interactions (Cunha-Filho & Sá-Barreto, 2008; Sobrinho et al., 2011).

The present study aimed to obtain and characterize the Epiisopiloturin–Hydroxypropyl-β-Cyclodextrin (EPI:HPβCD) inclusion complex, with the objective of overcoming its solubility limitations and advancing its potential as a therapeutic candidate against NTDs.

Theoretical Framework

The treatment of neglected diseases (NDs) continues to present urgent challenges. Many of the drugs currently available, such as those used in leishmaniasis therapy, are associated with high toxicity and adverse effects, which reduce patient adherence and therapeutic success. Moreover, the persistence of NDs is directly linked to the lack of investment in affordable drugs, reflecting the pharmaceutical industry's limited interest in populations with low purchasing power (Oliveira, 2006).

Within this context, natural products remain an important source for new therapeutic prototypes. Epiisopiloturin (EPI), an alkaloid derived from *Pilocarpus microphyllus* (jaborandi), has demonstrated significant schistosomicidal activity (Veras et al., 2012; Véras et al., 2013) and promising results against *Leishmania* spp., in addition to anti-inflammatory and antinociceptive effects (Guimarães, 2018).

Although EPI has shown strong pharmacological potential, its poor water solubility remains a major obstacle for pharmaceutical formulation development. One consolidated strategy to address this challenge is the formation of inclusion complexes with cyclodextrins (CDs), which has been widely employed to improve the solubility and bioavailability of several poorly soluble drugs (Wangsawangrung et al., 2022).

Methodology

Materials

Epiisopiloturin (EPI) was isolated and supplied by Anidro do Brasil Extrações S.A.® (Parnaíba, Brazil), following the procedure described by Véras et al. (2013). Hydroxypropyl-β-cyclodextrin (HPβCD) was kindly donated by Ashland Specialty Ingredients®. Distilled water was used as the vehicle in all experiments.

Methods

Phase solubility study

For the phase solubility study, excess EPI was added to aqueous solutions of HPβCD at different concentrations (1–50 mM). A control sample was prepared with distilled water only, to determine the saturation concentration of EPI. The suspensions were kept under constant agitation at 25 °C for seven days, followed by centrifugation. Supernatants were analyzed by UV–Vis spectrophotometry at 260 nm, as previously described for alkaloids with similar profiles (Véras et al., 2013).

Obtaining the physical mixture and inclusion complex by lyophilization

The physical mixture (PM) and the inclusion complex (IC) were obtained respecting the equimolar ratio (EPI:HPβCD), according to their respective molecular weights. Initially, to obtain the PM, the two constituents were weighed and then ground for one minute using a mortar and pestle and the resulting powder stored in an amber bottle in the desiccator.

To obtain the IC, the PM was poured into a two-liter beaker and distilled water was added, stirring at a constant temperature of 50°C for 6 hours or until completely solubilized. The resulting solution was kept in an ultrafreezer at a low temperature for 48 hours to achieve complete freezing. It was then subjected to the freeze-drying process at a pressure of around 30μHg and a temperature of approximately -55°C for a drying time of around 75 hours. The resulting powder was removed from the freeze-dryer (brand Liotop®, model L101) and stored in an amber bottle in a desiccator.

Physico-chemical characterization of the inclusion complex and the physical mixture

The obtained samples (pure EPI, physical mixture and inclusion complex) were subjected to physicochemical characterization to verify the efficiency of complexation, as recommended in previous studies (Figueiras et al., 2007). The selected techniques included Fourier-transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), X-ray diffraction (XRD) and dissolution profile analysis.

The reference data for pure EPI had been previously reported by Vieira (2017), serving as a comparative standard in this work.

Fourier Transform Infrared Absorption Spectroscopy (FTIR)

The infrared spectrum was obtained using PerkinElmer® equipment (Spectrum 400) with an attenuated total reflectance (ATR) device (Miracle ATR, Pike Technologies Spectroscopic Creativity) with a zinc selonide crystal. The samples to be analyzed were transferred directly into the compartment of the ATR device in triplicate. Scans were obtained from 400 to 4500 cm-1 with a resolution of 4 cm-1.

Thermal analysis - Differential Scanning Calorimetry (DSC)

The DSC curves for the thermal characterization of the samples were obtained using a Shimadzu® calorimeter, model DSC-60, in a temperature range of 30 to 300°C, under a dynamic nitrogen atmosphere with a flow of 100mL.min-1 and a heating rate of 10°C.min-1. A mass of 5mg (± 0.2) was used, packed in hermetically sealed aluminum sample holders. All tests were carried out in triplicate. The DSC was calibrated using the melting point of Indium (156.6 ± 0.3ºC) and Zinc (419.6ºC ± 0.3). Heat flow and enthalpy were calibrated using the melting point of Indium (18.59 J.g-1 ± 0.3), under the same conditions as the samples. The thermoanalytical data was analyzed using Shimadzu® software TA-60WS® (Therma Analysis) version 2.20.

X-ray diffraction (XRD)

The XRD analyses were carried out on Shimadzu® equipment, model XRD-600, using Cukα radiation of λ=1.5406Å. The time count was 0.6 seconds for each 0.02° step, with a scan interval of 5 to 50° (2θ). The diffractograms obtained were compared with the JCPD standard charts registered with the ICDD (International Center of Diffraction Data). These analyses were carried out at the Analytical Center of the Center for Strategic Technologies of the Northeast (CETENE) in Recife-PE.

In vitro dissolution tests

Dissolution tests were performed using USP apparatus II (paddle, 50 rpm) in 250 mL of phosphate buffer (pH 6.8, 37 ± 0.3 °C). Aliquots of 3 mL were withdrawn at predetermined time intervals (5–90 min) and immediately replaced with fresh medium to maintain constant volume. The procedure followed the general method described in the Brazilian Pharmacopoeia, 5th edition (Agência Nacional de Vigilância Sanitária, 2010). A sample amount equivalent to 10% of the EPI saturation solubility (5.5 mg) was used to ensure sink conditions.

At the end, the samples obtained were filtered through a 0.45 µm membrane filter and duly diluted for subsequent quantification of EPI by UV-vis spectroscopy at 220nm (Model B582, Micronal®), using the dissolution medium as the equipment's blank to eliminate possible interferents. The procedure was carried out in triplicate and the values were averaged. According to the results and with the help of the calibration curve, the EPI concentrations were determined at each collection time and the area under the curve (AUC) value was found using OriginPro® software.

CALIBRATION CURVE

The analytical curve used was obtained from the following concentrations: 260, 600, 800, 1000, 1600µg/mL, starting from a mother solution at 5000µg/mL. The absorbance values were determined using a spectrophotometer at a wavelength of 220nm, using the dissolution medium itself as a blank. The results obtained were to obtain the calibration curve. The straight line equation was obtained by linear regression using the OringPro® software.

Results and Discussion

Phase solubility study

The phase solubility method described by Higuchi & Connors (1965) is widely used to evaluate the formation of inclusion complexes. In this approach, the solubility of the compound is determined in solutions containing progressively higher concentrations of cyclodextrins, which makes it possible to estimate the stability constant and define the stoichiometric ratio of the complex at equilibrium (Higuchi & Connors, 1965). In the case of EPI, its poor absorption after oral administration has been reported, and one strategy to overcome this limitation is the preparation of inclusion complexes (Melo, 2015). As shown in Figure 1, the solubility of EPI increases as the concentration of HPβCD rises, displaying an AL-type profile as described by Higuchi & Connors, which is associated with the formation of a soluble complex (Cunha-Filho & Sá-Barreto, 2008).

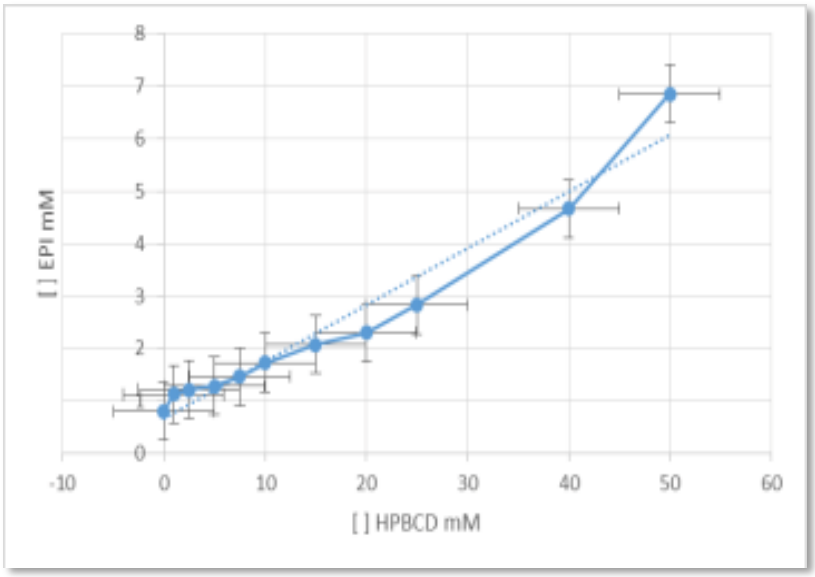

Figure 1. Phase solubility diagram of epiisopiloturine, with HPβCD in water at room temperature (25°C ± 0.5°C).
Source: Own authorship, 2018

The slope of the diagram was less than 1 (0.108191), suggesting the formation of a complex with a 1:1 ratio (m:m). Thus, there was an increase in solubility, which was initially 220.63 µg/mL and reached 1873.34 µg/mL at a concentration of 50 mM, an increase of 849.08%.

This behavior can be attributed to the presence of methyl substituents, which expand the cyclodextrin cavity and contribute to a structure that is more hydrophilic on the outside and hydrophobic on the inside. Such characteristics facilitate the accommodation of the active compound with greater flexibility (Castillo et al., 1999). In addition, the amphiphilic properties of cyclodextrins decrease the interfacial tension between the drug and the dissolution medium, which enhances the dissolution rate of the molecule (Mura, 2015).

Obtaining inclusion complexes by lyophilization

Figure 2 shows the process of obtaining the IC. Figure 2a shows the powder already dried and still in the equipment (Figure 2b), showing some of its macroscopic characteristics. It looks like a light powder that is easy to remove from the container. After the material has dried completely, a white agglomerate with a cotton-like appearance is formed, requiring maceration to break up this structure, obtaining a white powder with characteristics referring to the CD used (Figure 2c).

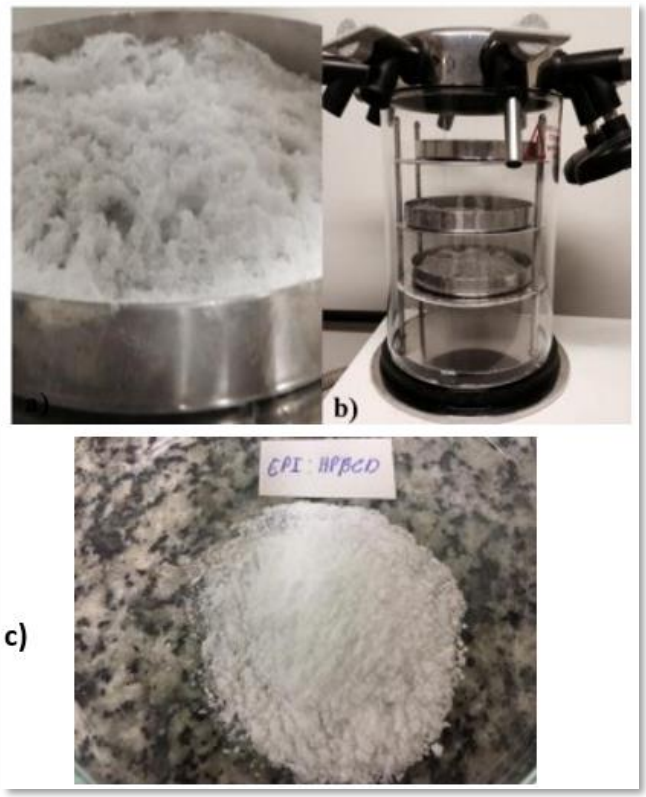

Figure 2. Images of the EPI:HPβCD inclusion complex, showing its macroscopic characteristics (Figure 2a), still in the lyophilizer (Figure 2b), white powder after grinding (Figure 2c).
Source: Own authorship, 2018

Physico-chemical characterization of the inclusion complex and the physical mixture

Absorption spectroscopy in the infrared region

Figure 3 has been divided into 4 parts which correspond to the most obvious bands in the EPI. Initially, it can be seen that the IC almost completely assumes a profile similar to that of the CD in question, serving as a strong indication of efficient complexation. Regions 2, 3 and 4 lack the defined, high-intensity bands present in EPI. For IC, region 1 still shows the presence of the characteristic band, but to a lesser extent, even compared to PM.

Moreover, the disappearance of minor peaks in the EPI spectrum suggests additional interactions between the compound and cyclodextrin, reinforcing the indication of complex formation (Figueiras et al., 2007).

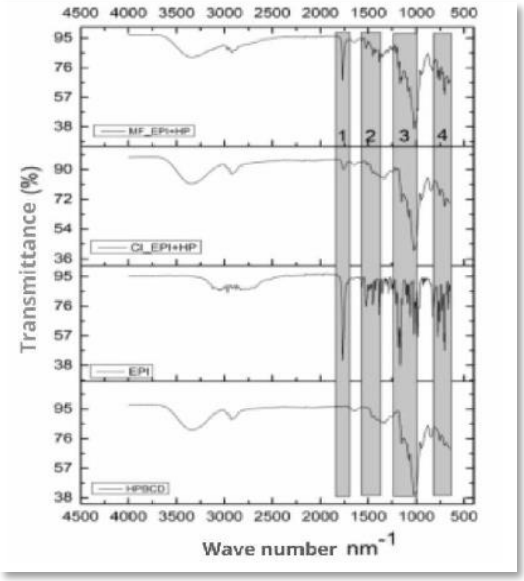

Figure 3. Infrared spectrum of the EPI:HPβCD inclusion complex and physical mixture samples, compared to the EPIISOPILOTURIN and HPβCD samples alone.
Source: Own authorship, 2018

Differential Scanning Calorimetry (DSC)

Differential Scanning Calorimetry (DSC) is a widely applied technique for investigating inclusion complexes in the solid state, since it provides thermodynamic evidence of interactions between the drug and cyclodextrin. Typically, modifications such as shifts in transition temperatures or the disappearance of melting peaks of the pure compound are considered indicative of complexation (Bayomi et al., 2002; Badr-Eldin et al., 2008; Mura, 2015).

Figure 4 shows the DSC thermograms of the physical mixture (PM) and the inclusion complex (IC) of EPI:HPβCD. The curve of pure EPI exhibits a sharp endothermic melting event between 216 and 223 °C, which is in agreement with data previously reported in the literature (Tiwari et al., 2010). In contrast, HPβCD presents a broad and asymmetric endothermic peak in the range of 124.6–145.15 °C, corresponding to the loss of water molecules commonly observed in cyclodextrins, and the absence of a distinct melting event due to their non-crystalline nature (Mura, 2015; Tiwari et al., 2010; Mendhe et al., 2016).

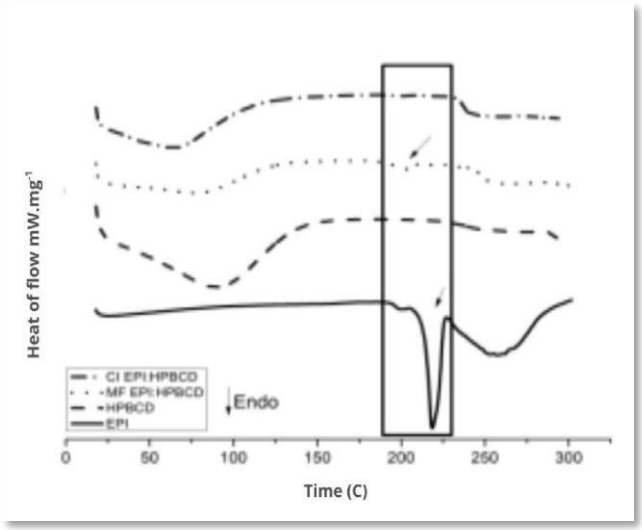

Figure 4. Differential exploratory calorimetry curves of epiisopiloturira, physical mixture and inclusion complex EPI:HPβCD, under a heating ratio of 10°C.min-1 and nitrogen flow of 50 mL.min-1.
Source: Own authorship, 2018.

For the physical mixture, a broad endothermic signal around 72 °C is observed, associated with dehydration of the CD, followed by a second event related to the melting of EPI. The reduced intensity of this melting peak indicates that simple mixing does not promote complexation, as the crystalline characteristics of the drug are still present (Tiwari et al., 2010; Mendhe et al., 2016; Haimhoffer et al., 2019).

In the case of the inclusion complex, the DSC curve does not show the melting event of EPI, which strongly suggests that the drug molecules are completely incorporated into the CD cavity. The absence of this transition is consistent with the formation of an amorphous system and provides evidence of effective interaction between the components (Figueiras et al., 2007; Sathigari et al., 2009; Sarabia-Vallejo et al., 2023). Complementary characterization techniques are nevertheless recommended to reinforce this interpretation.

X-ray diffraction

X-ray diffraction (XRD) is a standard method for evaluating the crystalline nature of compounds and has been extensively applied in the study of cyclodextrins and their inclusion complexes. By comparing the diffractograms of the pure drug, the physical mixture, and the inclusion complex, it is possible to detect modifications in solid-state properties, indicating molecular interactions between the components (Mura, 2015).

In this case, evaluating the diffractograms (Figure 5), EPI (5d) shows numerous diffraction peaks with high intensity and well defined, characteristic of crystalline material. This behavior was also observed for PM (5c), with a decrease in intensity related to the reduction in particle size during the preparation of PM, which can be considered an indication of interaction between the constituents of the mixture, but its crystalline character remains.

In contrast, the diffractogram of HPβCD (5b) exhibits broad and diffuse peaks, consistent with its amorphous nature (Silva et al., 2023). A similar pattern was observed for the inclusion complex (5a), supporting the occurrence of molecular encapsulation. Once incorporated into the CD cavity, EPI molecules cannot maintain intermolecular interactions necessary for crystallization, resulting in an amorphous final product. This finding is consistent with the DSC data, which also indicated the absence of crystallinity.

The tests were carried out in partner laboratories and on different equipment, so unfortunately it was not possible to standardize the scales, but this did not affect the results.

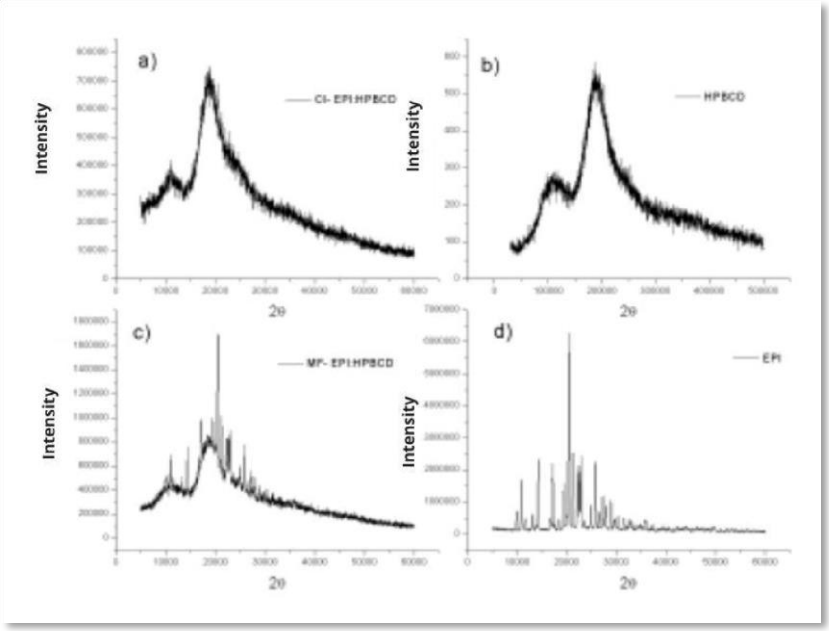

Figure 5. Diffractograms of epiisopiloturin (d), hydroxypropyl-beta-cyclodextrin (b), physical mixture (c) and inclusion complex (a).
Source: Own authorship, 2018.

Evaluation of the dissolution profile of Epiisopiloturine versus inclusion complexes.

Poorly water-soluble drugs usually present limited oral bioavailability, since dissolution is a key step for their absorption (Tiwari et al., 2010). Cyclodextrins have therefore been extensively explored as carriers to improve solubility and dissolution rates of such compounds. The positive effects of inclusion complexation are often related to modifications in the crystalline state of the drug, improved chemical stability, and increased wettability, which together enhance apparent solubility and pharmacological activity (Haimhoffer et al., 2019; Sathigari et al., 2009; Sarabia-Vallejo et al., 2023; Kumar et al., 2013; Sousa et al., 2020).

For the development of immediate-release formulations, dissolution testing can be conducted at single or multiple time points, or by constructing complete dissolution profiles. The latter approach, which follows the percentage of drug dissolved over time, provides the most reliable evaluation of dissolution efficiency and allows more robust comparisons between formulations (dos Santos, 2012).

It is possible to see the increase in its solubility, taking into account that in the first 5 minutes 100% of EPI is dissolved when it is in the form of IC EPI:HPβCD and approximately 19% when it is isolated.

After 15 minutes, the dissolution curve (Figure 6) reached a plateau, indicating an equilibrium between free and complexed EPI molecules in solution. Such equilibrium may influence the drug's absorption spectrum, leading to shifts or variations in maximum absorbance peaks. These changes are comparable to polarity effects observed with different solvents and support the hypothesis that the guest molecule is transferred from the aqueous medium into the hydrophobic cavity of cyclodextrins (Tiwari et al., 2010).

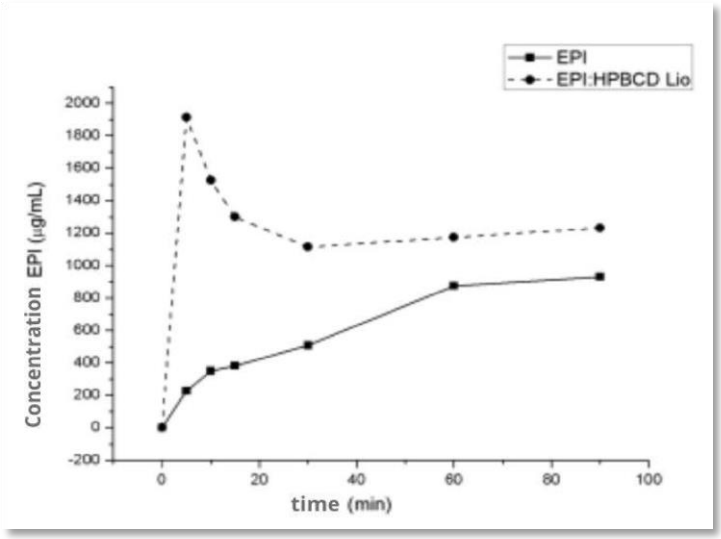

Figure 6. Dissolution profile of epiisopiloturine and EPI:HPβCD inclusion complex, evaluated by AUC values.
Source: Own authorship, 2018

An additional parameter for evaluating dissolution data is the calculation of the area under the curve (AUC). An increase in AUC values indicates enhanced dissolution efficiency, which may be associated with improved in vivo performance, since higher dissolution extent is generally correlated with greater drug bioavailability (Bhalani et al., 2022).

In the same figure, you can see the AUC value obtained for the EPI curve (AUC = 58427.5), while that of CI is almost double (AUC = 109017.5). This evaluation model correlates EPI concentration with time. Overall, it can be concluded that the formation of IC with HPBCD was able to increase solubility for better absorption of EPI and consequently promote an increase in its maximum concentration.

The physical mixture (PM) was not considered in this part of the discussion, since the inclusion complex (IC) results from the complete solubilization of EPI and HPβCD in aqueous medium under agitation. Under these conditions, the dissolution test itself mimics the complexation process, promoting higher apparent solubility of EPI. This effect is attributed to improved wettability and a reduction of interfacial tension

between solid particles and the solvent, which accelerates the dissolution rate (Haimhoffer et al., 2019; Sathigari et al., 2009; Sarabia-Vallejo et al., 2023; Kumar et al., 2013; Sousa et al., 2020; dos Santos, 2012; Bhalani et al., 2022; Rashid et al., 2019. Previous studies have shown that both PM and IC improve the dissolution profile of EPI compared to the pure drug, although the IC demonstrates superior dissolution efficiency and faster release kinetics (Melo, 2015).

Conclusions

It can be concluded that obtaining the complexation of EPI in HPβCD was satisfactory, which can be confirmed by the different techniques used, where the absence of the prototype in the results is strong evidence of interactions between them. The use of freeze-drying to obtain IC promoted a significant increase in the dissolution of EPI compared to pure and physically mixed forms.

In this way, the study successfully increased the solubility of EPI, but further analysis and dosing of EPI should be carried out in order to complement the information already found, with a view to obtaining the pharmaceutical form in the future.

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"The mil aulas tool in moodle for meaningful learning in entrepreneurship and management: A case study in ecuadorian high schools"

"Herramienta mil aulas en moodle para el aprendizaje significativo en emprendimiento y gestión: Un estudio de caso en bachillerato ecuatoriano"

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Abstract

The rapid and progressive advancement of computerized technology has compelled educational processes to migrate toward learning environments that require the use of digital platforms and tools. These environments foster the exploration and experimentation of contextualized didactic designs, with implications for the development of skills that transcend purely theoretical knowledge. This article aims to analyze the applicability of pedagogical methodologies for implementing collaborative practices among third-year students of the Unified General Baccalaureate (BGU) in Ecuador, specifically within the curricular unit of Entrepreneurship and Management, mediated by the Mil Aulas tool in Moodle. The theoretical framework is grounded in the approaches of Ausubel, 1983 and Siemens,

Resumen

El avance vertiginoso y progresivo de la tecnología informatizada ha generado en materia educativa, la migración forzosa de los procesos hacia entornos de aprendizaje que demandan el uso de plataformas y herramientas digitales que inducen a la exploración y experimentación de diseños didácticos contextualizado, con implicaciones en el desarrollo de habilidades que transcienden lo meramente teórico. Este artículo tiene como objetivo analizar la aplicabilidad de metodologías pedagógicas para implementar prácticas colaborativas en estudiantes de tercer año del Bachillerato General Unificado (BGU) en Ecuador, específicamente en la unidad curricular de emprendimiento y gestión, mediada por la herramienta Mil Aulas en Moodle. El marco teórico se sustenta en los enfoques de Ausubel, 1983 y Siemens, 2004, desde una perspectiva

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2004, from a socioconstructivist perspective. Methodologically, a non-experimental, cross-sectional design was adopted within a projective research approach, using a census sample of 90 students from the Tonchigüe High School in Atacames, Ecuador. Based on the average performance across the four groups, the findings indicate that mean scores increased by 90%, rising from 4.88 in the pre-test to 9.28 in the post-test. This result demonstrates a significant improvement in students' academic performance, strengthening their knowledge of markets and advertising, and contributing to meaningful learning.

Keywords: Educational environment, educational innovation, teaching method, pedagogical practice, ICT.

socioconstructivista. Metodológicamente, se optó por un diseño no experimental y transversal dentro de un enfoque de investigación proyectiva, con una muestra censal de 90 estudiantes del Colegio de Bachillerato Tonchigüe en Atacames, Ecuador. En base al promedio de los cuatro paralelos, los hallazgos muestran que las puntuaciones medias aumentaron en un 90%, pasando de 4.88 en el pretest a 9.28 en el postest. Este resultado evidencia un incremento significativo en el rendimiento académico de los estudiantes, fortaleciendo el conocimiento sobre el mercado y la publicidad, y contribuyendo al aprendizaje significativo.

Palabras clave: Ambiente educacional, innovación educacional, método de enseñanza, práctica pedagógica, TIC.

Introduction

The results of global studies conducted until 2023 by EntreComp and GEM (Global Entrepreneurship Monitor) on the development of entrepreneurial competencies in high school students worldwide show that, in Europe and Asia, the focus is high, emphasizing the development of critical thinking, creativity, and innovation. In the United States and Canada, it is also high; in Latin America, the level is medium due to limited teacher training, and in Ecuador, it is medium as well, but it is more centered on theories than on skills. This results in minimal development of labor competencies, limiting future labor insertion (Lasio et al., 2020; McCallum et al., 2020).

In the educational institution, Colegio Bachillerato Tonchigüe, where this study is focused, it is aligned with the national curriculum of the Ministry of Education, effective since 2016. The theoretical application prevails, with minimal practical implementation, resulting in only 40% of learning achievements, with minimal development of skills in Entrepreneurship and Management and digital competencies. One of the causes is the lack of teacher training in the use of digital technology and methodologies for applying these in the classroom, making it imperative to improve and address the inequality of opportunities this situation creates.

Technology has integrated into daily life in such a way that from an early age, individuals are immersed in smart devices, providing access to global information and communication. The constant use of technology raises questions about its effects on cognitive, emotional, and social development, and underscores the need to design educational strategies that take into account the opportunities and challenges of digital immersion for student growth and well-being (Höfrová et al., 2024).

The pedagogical approach to education must be comprehensive and based on the socioconstructivist model (Lev Vygotsky), and should align with the theories of meaningful learning (David Ausubel), Hebegogic theory in education, and connectivism according to George Siemens, which promote active student participation. Therefore, connectivism, as a learning theory, highlights the importance of knowledge networks and students' ability to connect and interact with various sources of information. This approach proposes that learning occurs individually, but it also nurtures interactions within a network of connections, facilitated by digital platforms like Mil Aulas. Through this environment, students can access content, collaborate, share ideas, and build collective knowledge. In this way, connectivism promotes the development of technological and cognitive competencies, preparing students to navigate an increasingly interconnected world, fostering flexible, autonomous, and collaborative education that meets the needs of the 21st century.

Within the educational sphere, Information and Communication Technologies (ICT), through the use of platforms, help the student's progress in the teaching-learning process, meaning they play an active role, transforming their role from passive receivers to active participants (Díaz Vera et al., 2021). Furthermore, the incorporation of ICT has been seen as a tool to reconfigure teaching methods and promote educational

innovation, responding to policies that aim to improve competitiveness and adapt schools to the demands of the 21st century. In this regard, virtual environments have been conceived as the key to the integral development of individuals, enabling them to face social changes and transformations (Bicalho et al., 2023).

The aim of this research is to analyze the impact of the use of virtual environments and digital tools to achieve competencies and skills for meaningful learning in the subject of Entrepreneurship and Management in Unit 3, Market and Advertising, taught to third-year General Unified Baccalaureate (BGU) students at Colegio Bachillerato Tonchigüe, located in Atacames, Esmeraldas.

This research follows a mixed approach (qualitative and quantitative), being descriptive in depth, with a non-experimental and cross-sectional design. The sources are both documentary and field-based. The theoretical methods employed were the theoretical-empirical method and the inductive-deductive method. The study used empirical methods (surveys, interviews, and pre-tests and post-tests, as well as mathematical statistics tools like SPSS), which allow for establishing the research phase of an improvement proposal: Mil Aulas.

In the social progress journey, achieving meaningful learning in students, particularly in the third year of the General Unified Baccalaureate (BGU) in Ecuador, mediated by virtual environments using the Mil Aulas tool, represents an important part of the formation process. This component allows students to create, innovate, decide, self-employ, and empower themselves with e-resources, transforming it into an ideal digital space that facilitates learning.

Furthermore, the transformation of the educational system requires the immersion of emerging paradigms in the conception of teaching and learning competencies and skills mediated by ICT, given the transcendence of theoretical boundaries in the delivery of content towards the use of digital methods and strategies. These refer to a series of metacognitive activities, as third-year BGU students belong to a generation that is socioculturally immersed in the digital era. Designing a virtual environment with the Mil Aulas tool on the Moodle platform for the Entrepreneurship and Management subject enables the development of skills, competences, and personal and professional development in a society that is aiming for significant changes.

Theoretical framework

Meaningful Learning in Virtual Environments

Education has gone through big transformations over time, and every change has left its mark. It is not just about moving from one teaching method to another, it is about the way people relate to knowledge itself. As Jasso & Villagran (2025) suggest, education has become a stage where teachers, students, and even policymakers play a role, and where methods and models are constantly questioned. Calderón et al. (2020) remind us that these shifts are not superficial: they affect how content is delivered, how it is absorbed, and even how experiences are lived. The truth is that the arrival of digital platforms has pushed this transformation faster than ever.

When we talk about meaningful learning, we are talking about a different way of teaching and learning, one that is deeper and more personal. Zurita et al. (2025) point out that this kind of learning can completely reshape how knowledge is built in the classroom. Vargas-Hernández & Vargas-González (2022) explain it well: meaningful learning happens when students connect new experiences with what they already know, and in doing so they do not just memorize, they truly make sense of what they are learning. Imagine a student who learns about market segmentation not by reading a definition, but by designing a small survey among classmates. That experience sticks, because it links theory to life.

Virtual environments are key in this because they give students room to go at their own pace and connect with others in ways that the traditional classroom often does not allow. Comas González et al. (2017) note that this flexibility is one of their strongest features. And yes, as Vergara et al. (2019) show, these tools can make training more effective. But, as Horna Li, & Seminario Unzueta (2023) warn, not everything is perfect: virtual learning also brings doubts and debates. Some students thrive in these spaces, while others get lost, distracted, or even discouraged. It is a double-edged sword.

There are also many flavors of virtual spaces. Vargas-Murillo (2021) and Rubio et al. (2022) talk about four in particular: structured e-learning platforms, personal blogs, collaborative wikis, and interactive social networks. Each has its strengths. Blogs can give students a voice, wikis build collective knowledge, and social networks create vibrant communities. But all of them share one condition: they only work if there is real preparation and feedback behind them (Albitres-Mendoza & Duran-Llaro, 2024). Otherwise, they risk becoming noise instead of tools. And we cannot ignore the hard reality: lack of connectivity, limited access to devices, and insufficient training for teachers are still obstacles that weigh heavily, especially in rural or vulnerable areas (Guarnizo Cajamarca et al., 2025).

And then come the bigger challenges. Beyond the technical issues, there is the question of how to keep students engaged for the long run. Anyone who has taught online knows this: one click away is social media, games, or distractions that can pull attention elsewhere. Motivation, self-regulation, even the sense of belonging, all of these are harder to maintain online (Horna Li, & Seminario Unzueta, 2023). The so-called digital divide is another thorny issue: it is not just about having or not having a laptop, it is about the quality of internet, the stability of the connection, the ability of a family to support that learning process.

And to be honest, many times schools simply move the same old methods online. A static PowerPoint on a shiny platform is still a static PowerPoint. As Bicalho et al. (2023) argue, the real challenge is to use digital environments to rethink pedagogy, not to digitalize tradition.

That is why training teachers is so crucial. Without updated skills, the tools stay underused, and their potential for fostering creativity, collaboration, and problem-solving is wasted (Díaz Vera et al., 2021). In the end, VLEs are like musical instruments: powerful, versatile, capable of beauty, but only in the hands of someone who knows how to play them.

So yes, virtual environments open enormous doors for meaningful learning, but they are not a magic bullet. They demand critical thinking, careful design, and above all, an awareness of their limits. The next step is clear: bridge the digital divide, support teachers with real training, and design environments that do not just move old practices to new screens, but genuinely invite students to learn in richer, more interactive ways. Only then will VLEs be more than platforms. They will be authentic bridges to deeper learning.

Implementation and Advantages of Mil Aulas in Moodle

The strategies and resources used in the educational field aim to guide teaching actions towards the management of learning processes that are aligned with the students' interests and expectations, with the goal of generating real transformations and changes in their way of knowing, doing, and internalizing content for the achievement of meaningful learning. According to Moreno-Laje et al. (2024), the design of didactic strategies supported by e-learning platforms seeks to meet the student's needs from the perspective of an individualized, interactive, and participatory scheme to develop skills in areas of interest, even in critical points.

In this sense, the most widely used tool in education is Mil Aulas, which offers “multiple activities, such as quizzes, consultations, databases, chat, forums, surveys, lessons, workshops, tasks, labels, books, wikis, among other free resources that favor interaction with the content” (Moreno-Laje, 2024, p. 6728), proving highly useful in education. For their part, Maji-Chauca et al. (2024) consider that Mil Aulas tools facilitate the strengthening and development of scientific skills and promote creativity and innovation. It is ideal for creating interactive and flexible virtual environments with digital resources and activities that foster active, collaborative, and meaningful learning. Similarly, Granados Muñoz (2021) mentions that it is applicable to all fields of knowledge, offering students, based on their needs and interests, more dynamic, motivating, and personalized learning experiences.

It is important to note that the Moodle platform and Mil Aulas operate under a negotiation system that makes it attractive to both the provider and the user, offering it free of charge.

It also presents certain advantages and disadvantages, as shown in Table 1. For de Sousa (2024), “Mil Aulas is a virtual platform that allows the teacher to be at the forefront of ICT, in addition to obtaining meaningful learning, as students build knowledge alongside their tutor” (p. 8).

Table 1.
Implementation, Advantages, and Disadvantages of Mil Aulas in Moodle

Implementation	Advantages	Disadvantages
Account creation and virtual classroom	Free	Advertising
Administration and configuration	Ease of use	Technical limitations
Automation	Quick access	Focus on small projects
Educational use	Popularity and Moodle support	

Note. This table summarizes the main strengths and weaknesses identified in the use of Mil Aulas, highlighting its accessibility and ease of integration, while also recognizing technical and functional constraints.

Based on the information presented by the cited authors, it is understandable that the Moodle platform is the most widely used by designers of virtual environments, not only in the business area but also across all disciplines of knowledge, presenting an opportunity to adapt and apply it in the educational field due to its free usage, ease of access-management, and the availability of a suitable environment that helps strengthen and develop skills, given the important set of digital resources commonly used in the teaching-learning processes within active methodologies.

Materials and Methods

The research adopts a mixed approach (quantitative–qualitative) that allows for both measuring and interpreting data. It is structured through an applied design with descriptive depth, as it seeks to understand the characteristics of the phenomenon, situation, or population, and it is cross-sectional since it analyzes variables collected over a specific period of time. The purpose is to verify whether the proposed pedagogical intervention generates significant changes in students' academic performance. For this reason, a pedagogical knowledge test aligned with the curricular program was designed and validated, and it was administered to the same group of students at two points in time: before the implementation of the Mil Aulas educational tool (pretest) and after it (posttest).

In addition, a survey was administered to third-year students immediately after the use of the Mil Aulas platform. The instrument included items organized in a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree), aimed at exploring multiple dimensions of the user experience: collaboration in activities, integration of technology, adaptability of the environment, speed of access, ease of navigation, connection between theory and practice, perceived academic improvement, and transfer of learning to different contexts. The survey allowed the collection of students' perceptions and levels of satisfaction to complement the quantitative results of the intervention.

For data processing, descriptive statistics (mean, median, and standard deviation) were first calculated for each item in the test and the questionnaire, mapping central tendencies and dispersion of responses. Subsequently, paired-samples t-tests were applied to compare pretest and posttest scores and to determine the statistical significance of the observed differences. All statistical analyses were performed using SPSS v.26.0, ensuring compliance with assumptions of normality and homogeneity of variance.

Population and Sample

The study population consisted of the 90 students enrolled in the third year of secondary education at Colegio de Bachillerato Tonchigüe, located in Atacames, Esmeraldas, Ecuador. Since the entire population was included, the study corresponds to a census, ensuring that the findings reflect the full group under study. To safeguard ethical standards, informed consent was obtained from both the students and their legal guardians, guaranteeing voluntary participation, confidentiality of responses, and adherence to research integrity principles for studies involving minors.

Theoretical Explanation

The study takes place over a five-week period, with a total of 10 hours of classes. In the first three weeks, the teacher applies the traditional methodology to teach the basic concepts. The students use the textbook provided by the Ministry of Education of Ecuador, covering the following content:

- **Week 1**: Market segmentation and the variables that make it up;
- **Week 2**: Advertising techniques and the creation of a commercial advertising plan;
- **Week 3**: Aspects related to safety and health within an entrepreneurship, and the pretest is applied. This initial evaluation determines the students' prior knowledge regarding the topics covered, guiding the teaching and learning process.
- **Weeks 4 and 5**: The use of the Mil Aulas platform, which is structured with interactive activities, digital resources, and formative assessments that reinforce the previously covered content, promoting a more active and participatory learning approach by the students (see Table 2). On the other hand, in the fifth week, the posttest is applied to evaluate the learning achieved at the end of the instructional process.

Table 2.
Structure of the Mil Aulas Platform Used During the Fourth and Fifth Weeks

Section	Content / Activity	Explanation
General Topic	The market and advertising	Central theme guiding the development of activities. Introduces students to market analysis and advertising strategies.
Unit Introduction	Introductory video from YouTube on digital advertising	An audiovisual resource is used to capture attention and contextualize the topic from a current perspective.
Doubt Forum	Open space for students to express their questions	Encourages active participation, critical thinking, and collaborative problem-solving.
Discussion Forum	Guiding question: What reasons would make you agree to start an entrepreneurship?	Stimulates personal reflection on entrepreneurship, linking learned concepts with real-life experiences and aspirations.
Topic Explanation	Conceptual development of content related to market, segmentation, advertising, and entrepreneurship.	Provides the theoretical foundation needed to understand and apply the topics.
Resources	Tab with explanatory videos for each subtopic and space to create a glossary.	Reinforces autonomous learning and promotes the creation of a glossary as a study tool.
Activities	Practical exercises applied to the student's environment.	Allows the concrete application of theoretical knowledge, developing practical skills.
Final Product	An entrepreneurship uses Suma CRM, an online service, to manage its sales force negotiations.	Evaluates the practical application of the learned concepts.
Summative Evaluation	Test covering content discussed during the five weeks. TOP 10 CRM Gratuito | Mejores Sistemas CRM Gratis 2025	Assesses the level of understanding and ownership of the content by the students.
Feedback (Games)	Interactive activities to reinforce learning: Desafío de emprendimiento y mercado – Educaplay Liveworksheet – Emprendimiento	Helps consolidate knowledge in a dynamic and interactive way, integrating games as a pedagogical strategy.

Note: This structure summarizes the activities implemented during weeks four and five, combining theory, practice, and gamified resources to promote meaningful learning in Entrepreneurship and Management.

The proposal is implemented through the Mil Aulas virtual learning environment, a digital educational platform structured with a dynamic and interactive instructional design. This tool enables the progressive sequencing of content, promoting active student participation through multimedia resources, collaborative forums, and evaluative activities. Below is the QR code that directly links to the access to the platform.

Figure 1. QR Code to Access the Mil Aulas Platform: The Market and Advertising
Note: To enter, use the following credentials: username **admin** and password **1305966044Israel**.

This improvement proposal has been validated by five experts: two in pedagogy, two in technology, and one in the subject of Entrepreneurship and Management. The validation considered the indicators of clarity, coherence, relevance, and pertinence across the 18 aspects involved in the development of the proposal, with 100% approval.

Results

Comparison of Posttest and Pretest Pedagogical Test Results

The results show a consistent increase in the means of the groups evaluated before and after the intervention (see Table 6). In parallel A, the mean increased from 4.59 to 9.00; in parallel B, from 5.08 to 9.68; in parallel C, from 5.01 to 9.35; and in parallel D, from 4.83 to 9.07. Additionally, in all cases, both the median and mode increased, which reinforces the trend towards a generalized improvement in student performance. The standard deviations were reduced in most cases, suggesting greater homogeneity in the results after the intervention.

Table 3.
Descriptive Statistics of the Pretest and Posttest

N	Mean	Median	Mode	SD	Min	Max
Before A	25	4.59	5.00	5.00	1.445	2.00
After A	25	9.00	9.00	9.00	0.645	8.00
Before B	25	5.08	5.00	5.00	1.305	3.00
After B	25	9.68	10.00	10.00	0.424	9.00
Before C	20	5.01	5.65	3.00	1.751	2.00
After C	20	9.35	9.50	10.00	0.714	8.00
Before D	20	4.83	5.00	5.00	1.590	2.00
After D	20	9.07	9.00	9.00	0.673	8.00

Hypothesis Testing

- **Null Hypothesis (H_0):** $\mu = 0$. There is no significant difference between the means before and after the intervention (the improvement is null or random).
- **Alternative Hypothesis (H_a):** $\mu \neq 0$. There is a significant difference between the means before and after the intervention (there is a real improvement in learning).

Table 4.
T-test for Paired Samples

			T-Statistic	df	p-value
Before A	After A	Student's T	-14.64	24.0	< .001
Before B	After B	Student's T	-17.10	24.0	< .001
Before C	After C	Student's T	-9.79	19.0	< .001
Before D	After D	Student's T	-10.58	19.0	< .001

Note: H_a μ Measure 1 - Measure 2 ≠ 0

The results of the paired samples T-test show statistically significant differences between the scores before and after the intervention in all the analyzed groups. In all four cases (A, B, C, and D), the T-statistic values are high and negative, indicating a consistent improvement in the post-intervention scores. Moreover, the p-values < .001 in all groups confirm that the observed differences are not due to chance. Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted: there is a significant change in student performance following the intervention.

Survey Results from Students

The results obtained from the Likert-type questionnaires applied to the third-year students of the General Unified Baccalaureate at Colegio de Bachillerato Tonchigüe are presented below:

Table 5.
Likert-type Questionnaire Propositions: Item 1, Item 2, and Item 3

Propositions	The tools in virtual environments promote active collaboration	The inclusion of technology in education improves learning	The implementation of a virtual environment in Mil Aulas improves learning
Strongly Disagree	1	0	0
Disagree	3	0	1
Neither Agree nor Disagree	15	13	23
Agree	53	38	45
Strongly Agree	18	39	21
Total	90	90	90

Source: Data taken from third-year students at Colegio de Bachillerato Tonchigüe (2025).

The results in Table 5 show a positive trend regarding the use of technological tools and virtual environments, particularly the Mil Aulas platform. In Item 1, related to active collaboration fostered by virtual tools, 53 students agreed, 18 strongly agreed, and 15 were neutral, indicating that the majority believes virtual tools facilitate interaction and collaborative work. Item 2, related to the improvement of learning through the inclusion of technology, also presents a favorable response, with 39 students strongly agreeing, 38 agreeing, and 13 being neutral, reflecting a positive perception about the influence of technology on academic performance.

In Item 3, which evaluates the implementation of a virtual environment in Mil Aulas, 45 students agreed, 21 strongly agreed, and 23 were neutral. These results suggest that the majority value the benefits of Mil Aulas, although a significant group of students still have reservations or do not fully perceive the improvement in their learning. The analysis of this data leads to the conclusion that, overall, students appreciate digital tools and virtual platforms as learning facilitators, although some may need more time or adjustments in using the platform to fully experience these benefits.

Table 6.
Likert-type Questionnaire Propositions: Item 4, Item 5, and Item 6

Propositions	Mil Aulas allow adapting activities according to needs	Mil Aulas allow finding information and resources quickly	Resources and activities in Mil Aulas are intuitive
Strongly Disagree	0	0	0
Disagree	3	1	1
Neither Agree nor Disagree	21	13	17
Agree	48	56	58
Strongly Agree	18	20	14
Total	90	90	90

Source: Data taken from third-year students at Colegio de Bachillerato Tonchigüe (2025).

In Table 6, the results show a mostly positive evaluation regarding the functionalities of Mil Aulas. For Item 4 on whether Mil Aulas allows adapting activities according to needs, 18 students strongly agreed, 48 agreed, and 21 were neutral, indicating that most students believe the platform facilitates adequate personalization of activities. In Item 5, on the speed of finding information and resources in Mil Aulas, 20 students strongly agreed, 56 agreed, and 13 were neutral, highlighting the accessibility of resources on the platform. Finally, in Item 6 regarding the intuitiveness of the resources and activities in Mil Aulas, 14 students strongly agreed, 58 agreed, and 17 were neutral, reflecting that most students find the platform easy to use.

Overall, the results suggest that the Mil Aulas platform is well-received by students, who positively value its ability to adapt to their needs, facilitate access to resources, and offer an intuitive interface. However, there is a 19% who remain neutral or disagree, indicating areas where the experience or customization of the platform needs improvement.

Table 7.
Likert-type Questionnaire Propositions: Item 7, Item 8, and Item 9

Propositions	In the Mil Aulas platform, synchronous and asynchronous activities can be done	The Mil Aulas platform facilitates the learning of entrepreneurship and management	It links the concepts, skills, and competencies learned in entrepreneurship and management
Strongly Disagree	1	0	0
Disagree	2	2	1
Neither Agree nor Disagree	20	7	17
Agree	47	55	58
Strongly Agree	20	26	14
Total	90	90	90

Source: Data taken from third-year students at Colegio de Bachillerato Tonchigüe (2025).

Regarding Table 7, Item 7 shows that when performing synchronous and asynchronous activities, the majority of students (47 agreed and 20 strongly agreed) believe the platform provides adequate flexibility in the learning mode. Moreover, in Item 8, most students also perceive that the platform facilitates the learning of entrepreneurship and management, with 55 students agreeing and 26 strongly agreeing, highlighting the effectiveness of the tool in supporting this specific area.

For Item 9, which evaluates the linking of concepts, skills, and competencies learned in entrepreneurship and management, the platform also received a positive evaluation, with 58 students agreeing and 14 strongly agreeing. These results indicate that students feel Mil Aulas significantly contributes to integrating what has been learned with practice. However, despite the 80% positive perception, 20% remain neutral or disagree, suggesting that there are still areas that need improvement to optimize the learning experience on the platform.

Table 8.
Likert-type Questionnaire Propositions: Item 10, Item 11, Item 12, and Item 13

Propositions	The activities of the proposal in the Mil Aulas virtual environment improve academic performance	They apply what they learned in the virtual environment in contexts outside the educational environment	The Mil Aulas virtual environment stimulates interest by promoting research and meaningful learning	Technological tools in the educational field are fundamental at Colegio de Bachillerato Tonchigüe
Strongly Disagree	0	2	1	0
Disagree	3	3	1	2
Neither Agree nor Disagree	15	15	16	10
Agree	51	44	48	32
Strongly Agree	21	26	24	46
Total	90	90	90	90

Source: Data taken from third-year students at Colegio de Bachillerato Tonchigüe (2025).

For Item 10, regarding whether the activities in Mil Aulas improve academic performance, the majority of students (51 agreed, 21 strongly agreed) consider that these activities have a positive effect on their performance. Similarly, in Item 11, a significant number of students (44 agreed, 26 strongly agreed) agree that what they learned in the virtual environment can be applied in contexts outside the educational field. Regarding Item 12, which evaluates whether Mil Aulas stimulates interest by promoting research and meaningful learning, 48 students agreed and 24 strongly agreed, indicating that the platform motivates interest and curiosity for deeper learning. Finally, in Item 13, related to the importance of technological tools at Colegio de Bachillerato Tonchigüe, 32 students agreed and 46 strongly agreed, reflecting that technology is necessary for learning.

In general, the results reveal a positive evaluation of Mil Aulas as a tool that improves academic performance, encourages the practical application of knowledge, stimulates research, and fosters meaningful learning. However, 13% of students remain neutral or disagree with some of the items, suggesting that there are areas of the platform that need improvement to ensure that all students benefit equally.

Discussion.

The triangulation between the theoretical framework, the educational reality, and the proposed solution through the Mil Aulas tool highlights how technological mediation transforms the teaching-learning process. From the socioconstructivist paradigm, meaningful learning is achieved when the student actively constructs knowledge by articulating previous experiences with new contextualized situations (Miranda-Núñez, 2022). This approach is particularly relevant in subjects such as Entrepreneurship and Management, where academic knowledge must be integrated with practical skills.

The educational reality at the General Unified Baccalaureate level shows that many students have difficulty transferring theoretical knowledge to real-life contexts. In this sense, the use of digital platforms like Mil Aulas provides a flexible, participatory, and personalized environment, addressing the diversity of learning styles and paces (Lino-Calle et al., 2023). The incorporation of interactive resources, such as discussion forums, audiovisual materials, and educational games, appears to have had the greatest impact. Forums encouraged students to exchange perspectives, strengthening collaborative learning. Videos provided accessible explanations that complemented the textbook, while gamified activities-maintained motivation and transformed routine tasks into engaging challenges. These elements help explain why students reported higher levels of satisfaction and performance.

From the pedagogical intervention perspective, a mixed strategy was developed in two phases: the first with the traditional approach based on the school textbook, and the second supported by the Mil Aulas environment with its digital resources and evaluative activities. This transition reflects what Moreno-Laje et al. (2024) argue: digital environments foster creative thinking, problem-solving, and

learning autonomy. The clear improvement in test scores suggests that the dynamic sequencing of content and the variety of activities offered through Mil Aulas allowed students to better connect theory with practice.

The instructional design included logical sequencing of content, use of relevant digital resources, and the application of a posttest evaluation. According to Andrade et al. (2023), virtual environments that integrate meaningful, collaborative, and contextualized activities enhance knowledge transfer. In this study, the combination of pretest–posttest comparisons with participatory activities confirmed that students not only improved academically but also developed transferable skills relevant to the workplace.

The survey results also provide insights into how students perceived the platform. In Items 1, 2, and 3, they highlighted the role of digital tools in strengthening collaboration and academic performance. This supports Bell et al. (2024), who stress that horizontal interaction and shared knowledge construction are fundamental for active learning. However, a significant proportion of students responded "neither agree nor disagree," which suggests that not all students fully experienced these benefits. This neutrality may indicate that some learners require more time, support, or adaptation of activities to take full advantage of the platform.

Similarly, Items 4, 5, and 6 revealed positive perceptions of task adaptability, ease of access, and intuitive design, aligning with the technology acceptance model (Pinargote et al., 2024). Still, around 19% of responses were neutral or negative, pointing to areas of improvement in personalization and user experience. These findings highlight that while Mil Aulas is generally well-received, continuous refinement is necessary to ensure inclusivity and engagement for all students.

Finally, Items 7 to 13 showed strong support for Mil Aulas in terms of promoting synchronous and asynchronous learning, stimulating research interest, and consolidating competencies in entrepreneurship and management (Manotoa-Labre et al., 2025). Nevertheless, it is important to acknowledge the limitations of this study. The intervention lasted only five weeks, which may not be enough to measure long-term learning consolidation. Furthermore, the context was limited to one institution, making it necessary to replicate the study in other schools and curricular areas.

In summary, the results confirm the potential of Mil Aulas to improve meaningful learning by combining interactive, collaborative, and gamified strategies. However, the presence of neutral responses, the short intervention period, and the contextual limits of the study indicate that future research should deepen the analysis of student diversity, expand the timeframe, and explore strategies to maximize engagement for all learners.

Conclusions

The use of the Mil Aulas tool has proven to be an effective resource for strengthening students' understanding of market dynamics and advertising practices. It fosters both conceptual and procedural skills through a learning experience that is collaborative, flexible, participatory, and motivating. Its accessibility from any environment with internet connectivity further expands its value, showing that digital tools can transcend the limits of traditional classrooms. The evidence obtained in this study demonstrates that the proposed didactic strategy effectively raises the level of meaningful learning in this curricular area.

With respect to the variable "Implementation and Advantages of Mil Aulas in Moodle," the Hebegogic approach fostered high levels of engagement, with more than 90% of students actively participating in activities. This promoted the consolidation of core content on market and advertising within the Entrepreneurship and Management unit of the third-year General Unified Baccalaureate (BGU). Moreover, the digital environment helped address long-standing teaching challenges, making the integration of ICT more natural and functional. The activities designed encouraged students to take ownership of their learning process through collaboration, reflection, and responsibility, both in synchronous and asynchronous sessions.

Concerning the variable "Meaningful Learning in Virtual Environments," students recognized the broad applicability and practicality of Mil Aulas as a didactic mediator. The experience not only reinforced the program contents but also demonstrated the sustainability and feasibility of incorporating virtual platforms in formal education. These findings highlight that the effectiveness of Mil Aulas lies in its capacity to

combine innovation with pedagogical consistency, ensuring that students experience learning as a dynamic and contextualized process.

The pilot study confirmed improvements in the competencies acquired. The application of digital skills enhanced academic performance while also transferring to professional contexts. This dual impact shows an evident growth in both digital and professional abilities, preparing students with a more versatile profile to face the challenges of the current labor market. Nevertheless, this study also opens new questions: What would be the long-term impact of continuous use of Mil Aulas on learning outcomes? Could similar results be obtained in other curricular areas beyond Entrepreneurship and Management? And to what extent can these platforms contribute to reducing educational inequalities in diverse contexts? These questions point to future research directions that would enrich the field and provide greater originality to studies on virtual learning environments.

Beyond the specific findings, this research contributes to the broader debate on how emerging technologies can reshape educational practices in Ecuador and Latin America. While Moodle and Mil Aulas are widely known, their contextualized application in the BGU demonstrates that, when properly designed, virtual learning environments can become instruments for equity, inclusion, and educational innovation. By situating this study in a local context while connecting it to global debates, the article offers insights not only for immediate implementation but also for the long-term rethinking of how digital platforms can transform teaching and learning in diverse educational systems.

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Análise das ações de formação profissional e desempenho dos funcionários públicos em Moçambique, caso da Universidade Zambeze (2018-2022)

Analysis of Professional Training Actions and Performance of Public Servants in Mozambique, Zambezi University Case (2018-2022)

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Resumo

A pesquisa objetiva analisar as ações de formação profissional e desempenho dos Funcionários Públicos em Moçambique, caso da Universidade Zambeze (UniZambeze), na sequência da Estratégia Global da Reforma do Sector Público, lançada pelo Governo, em Junho de 2001. Trata-se de uma orientação ao conjunto das instituições públicas a melhorar a qualidade de serviços e das respostas do Estado à sociedade. A questão da pesquisa procura aferir de que modo as ações de formação profissional dos funcionários do Corpo Técnico Administrativo (CTA) da UniZambeze contribui no melhoramento do seu desempenho profissional. Quanto aos procedimentos técnicos é pesquisa exploratória, de natureza aplicada e abordagem qualitativa, visto que visa proporcionar uma visão geral sobre o impacto das ações de formação profissional no desempenho dos funcionários públicos e os sujeitos da investigação são o CTA da UniZambeze. Constatou-se que anualmente os funcionários são submetidos a cursos de formação profissional e cursos conducentes ao grau, para responder novas exigências, desafios, globalização, mudanças comportamentais, reforço às condições de trabalho, melhoria das qualificações e desempenho dos funcionários. Portanto, os dados indicaram que a formação profissional dos funcionários do CTA contribui no seu desenvolvimento profissional e na melhoria do desempenho.

Palavras-Chave: Avaliação de Desempenho, Desempenho, Formação Profissional.

Abstract

The research aims to analyze the professional training actions and performance of Public Servants in Mozambique, such as the Zambeze University (UniZambeze), following the Global Public Sector Reform Strategy, launched by the Government in June 2001. This is guidance for all public institutions to improve the quality of services and the State's responses to society. The research question seeks to assess how professional training actions for employees of UniZambeze's Administrative Technical Body (CTA) contribute to improving their professional performance. Regarding technical procedures, it is exploratory research, of an applied nature and a qualitative approach, as it aims to provide an overview of the impact of professional training actions on the performance of public servants and the subjects of the investigation are the CTA of UniZambeze. It was found that employees annually undergo professional training courses and courses leading to a degree, to respond to new demands, challenges, globalization, behavioral changes, reinforcement of working conditions, improvement of employee qualifications and performance. Therefore, the data indicated that the professional training of CTA employees contributes to their professional development and improved performance.

Keywords: Evaluation Performance, Performance, Professional Training.

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Introdução

Devidos as exigências impostas pela tendência cada vez mais dinâmica e competitiva das instituições públicas e privadas na atualidade, é necessário atuar, acompanhar e verificar a dedicação de todos funcionários que se vinculam a uma instituição, através da formação contínua e extensiva. Contudo, é comum em tempos de mudanças que se note sentimentos de ansiedade e de resistência referente a algo novo e desconhecido.

O processo de formação como um todo é complexo pois, existem várias abordagens sobre a formação. Contudo, vamos nesta pesquisa abordar a formação profissional, aquela que pode ser oferecida aos servidores públicos no sentido de melhorar o desempenho profissional. Procuramos com isso analisar as ações de formação profissional e o desempenho dos funcionários públicos, por forma a permitir a flexibilidade na adaptação perante as mudanças no mercado.

Por outra parte, a Estratégia Global da Reforma do Sector Público em Moçambique foi oficialmente lançada pelo Governo em Junho de 2001, como corolário das reformas políticas, económicas e sociais iniciadas em 1975, com a criação do Estado Moçambicano. A mesma orienta o conjunto das instituições públicas a melhorar a qualidade de serviços e das respostas do Estado à sociedade, através da adequação do funcionamento das instituições públicas aos desafios internos e externos que requerem uma cultura pública virada à integridade, transparência, eficiência e eficácia.

A Componente 3 do Programa de Reforma do Sector Publico 2006-2011, defende a profissionalização dos funcionários do Sector Público através da estratégia de desenvolvimento do Sistema de Formação em Administração Pública, porém, nos dias atuais, constata-se que a participação em cursos de formação ocorre de forma massiva com registro de números de servidores públicos submetidos em cursos de formação financiados por conta própria, e outros com bolsas de estudo financiadas pelo Governo ou outros parceiros, mesmo sem indicação clara da relevância dos cursos, ou a necessidade de enquadramento nas respetivas instituições. Este facto suscita a questão de partida para a pesquisa: até que ponto as ações de formação profissional contribuem no desempenho dos funcionários do Corpo Técnico e Administrativo (CTA) da Universidade Zambeze (UniZambeze)?

Com a reforma do Sector Público em Moçambique, as instituições devem investir em estratégias de formação assumindo novas responsabilidades pessoais pelo desempenho individual necessário ao cumprimento das metas e objetivos institucionais, promovendo o crescimento dos funcionários. Portanto, cabe às instituições, procurar oferecer constante acompanhamento nas tendências do mercado e o meio envolvente competetivo que se tem mostrado dinâmico, e incentivar o empenho de todos os servidores públicos permitindo assim uma formação contínua.

A UniZambeze foi criada como instituição de natureza pública, conforme prevê o Decreto n° 74/2011 de 30 de Dezembro (Conselho de Ministros, 2011), resultado dos esforços do Governo de Moçambique na redução das assimetrias regionais e de aumento das possibilidades de acesso ao Ensino Superior público a nível nacional. Portanto, a formação profissional em particular na UniZambeze, é um instrumento relacionado ao desenvolvimento profissional dos funcionários, ou seja, um processo contínuo de ampliação do potencial através de ações de indução, que visam o crescimento profissional do funcionário e melhoria da qualidade de serviços oferecidos aos utentes.

O estudo tem por objetivo analisar as ações de formação profissional e desempenho dos funcionários públicos em Moçambique. Foi considerada a hipótese de que apostar na formação profissional dos funcionários, pode contribuir de forma positiva para melhorar o desempenho profissional e aumentar a produtividade nas instituições publicas, mas também não se descarta a hipótese de que a formação profissional pode não produzir mudanças de comportamento dos funcionários e com isso criar situações de acomodação nas funções e consequente baixo desempenho.

O estudo é relevante na medida em que pode contribuir para uma reflexão sobre a necessidade de promover ações formativas dos funcionários públicos que se adequem às exigências de cada sector, por forma a desenvolver competências individuais e assegurar o desenvolvimento do desempenho profissional. No campo da ciência, o estudo pode estimular novas abordagens sobre os critérios de acompanhamento do desempenho profissional dos funcionários após a conclusão do processo de formação.

A seguir da introdução, apresenta-se a revisão da literatura onde descrevemos de maneira concisa as teorias que sustentam o estudo, seguida da metodologia aplicada, análise e discussão de dados e por último apresentamos as conclusões.

Revisão da Literatura

Entre vários os autores que dedicam estudos para analisar processos de formação profissional, destaca-se Lourenço (2015), que defende a formação profissional como a aquela que tem por objetivo adotar os indivíduos de competências com vista ao exercício de uma ou várias atividades profissionais. Porém, o ensino e a formação têm como objetivo de adotar os indivíduos de conhecimentos teóricos e práticos, capacidades e ou competências exigidas por profissões específicas ou pelo mercado de trabalho.

Para Lourenço (2015), a formação profissional deve ser continua; ela é uma atividade de educação empreendida após a saída do sistema de ensino ou após o ingresso no mercado de trabalho, que permite ao indivíduo aprofundar as competências profissionais e relacionais tendo em vista o exercício de uma ou várias atividades profissionais. È uma adaptação das mutações tecnológicas e profissionais, para sua melhor empregabilidade e favorecer a promoção profissional. A formação profissional melhora a qualidade de emprego e contribui para o desenvolvimento cultural, social e económico.

Ao abordar a formação profissional sob ponto de vista dos objectivos, de Oliveira Rocha (2010), considera que ela visa aumentar a capacidade das pessoas sob ponto de vista profissional. A formação profissional levada a cabo pelas organizações, visa dentre outros objetivos: aumentar os conhecimentos dos beneficiários; modificar atitudes; melhorar a eficiência, eficácia e a qualidade dos produtos e serviços; melhorar o desempenho profissional pelo fomento da criatividade, inovação, e do espírito de iniciativa.

Essas abordagens transmitem a ideia de que qualquer tipo de formação dos funcionários constitui uma ferramenta destinada a preparar o indivíduo para o desempenho de uma função específica ou atividade. Seus propósitos são tanto para o curto, médio ou longo prazo, pois a formação tem como intuito qualificar o indivíduo para uma futura carreira e pode ser oferecida nas instituições de ensino, assim como na própria empresa.

Uma pesquisa levada a cabo por Nhamoneque (2018), constatou que, à luz da teoria de formação de competências, os cursos frequentados pela maioria dos funcionários contribuem para a sua especialização, quando abordam matérias profissionais, ou seja, ligadas com as suas funções rotineiras, o que pode ainda contribuir para a sua eficácia e desempenho na função.

Contudo, pode-se entender que para o exercício da atividade profissional, é necessário possuir conhecimentos teóricos ou práticos sobre as funções que vai desempenhar como uma ferramenta do sucesso. Assim, só através de investimentos na formação do pessoal, as organizações podem assegurar que os seus colaboradores estejam dotados de habilidades e competências no desempenho das suas funções dentro da organização, elevar o saber ser, as capacidades manuais situadas ao nível do saber-fazer, e desenvolver as atitudes de comunicação.

Levieque (2011), considera que a formação não é coisa que se possa fazer ou não segundo as conveniências. Quer formal ou informalmente, com ou sem o seu conhecimento, em todas as organizações o pessoal recebe formação, porém, o problema reside em saber como formar. Ao decidir como proporcionar a formação, tanto o gestor como o pessoal formador, deve ter em mente as seguintes linhas de orientação:

a) A aprendizagem ocorre no local de trabalho como resultado da intervenção dos seguintes fatores - aptidões individuais do funcionário, (a sua capacidade, as atitudes, aspirações, percepções e os receios); o posto de trabalho (as exigências, desafios e necessidades).
b) A formação e o desenvolvimento devem ser vistos mais como um processo permanente, do que como um programa a curto prazo.
c) Os esforços do desenvolvimento devem evitar mudanças na personalidade. Deve pelo contrário, focar a atenção na mudança do conteúdo de trabalho, mediante a criação de novas responsabilidades e nova autoridade.

Podemos afirmar que a formação deve ser vista como um processo contínuo levado a cabo no dia-a-dia no posto de trabalho, na medida em que o funcionário vai exercendo as suas atividades, aperfeiçoando os

métodos e instrumentos de trabalho, na busca de soluções das dificuldades que enfrenta, e melhoria da qualidade dos produtos e serviços. Assim, a formação profissional deixa de ser abordada como uma mera obrigação legal para as empresas, mas sim, como um veículo para melhorar a sua performance como um todo, ela incrementa a produtividade e rentabilidade, e reaviva e atualiza conhecimentos dos funcionários.

Segundo Chiavenato, (2015) a base principal para os programas de melhoria contínua é a constante capacitação das pessoas para patamares cada vez mais elevados de desempenho. È um processo contínuo composto por quatro etapas, sendo elas: diagnóstico (responsável pelo levantamento de necessidade ou carências); Desenho (elaboração do projeto ou do programa); implementação (condução e execução do programa); e avaliação (verificação dos resultados obtidos).

Andifoi (2010), citado por Nhamoneque, (2018), afirma que é necessário integrar a formação profissional contínua no quadro das prioridades das organizações, por forma a responder as exigências de desenvolvimento do País, conceber a formação profissional contínua como uma perspetiva estratégica para o desenvolvimento em prol da melhoria do desempenho da Função Pública em Moçambique.

Para de Oliveira Rocha (2010), o processo de formação inclui 4 fases: diagnóstico da situação, programação, implementação e avaliação.

a) Diagnóstico das necessidades de formação: é a fase em que deve se levar a determinação das necessidades de formação; consiste na identificação das lacunas da formação, oque se faz usando várias técnicas: questionário, entrevista, análise em grupo e grupos diagnósticos. O diagnóstico também pode visar a identificação das competências de que estratégia a organização necessita; e a análise da performance que consiste em determinar o desempenho exigido por cada tipo de função e comparação com os resultados concretos de forma a incluir pela necessidade de formação adequada.
b) Programação da formação: uma vez feito o diagnóstico da situação, há que escolher os meios adequados de tratamento, de forma a sanar as deficiências. Faz parte do fazer de programação (a determinação do número de participantes, seleção com base no interesse da organização e das capacidades dos candidatos, organização do curriculum das matérias, elaboração de normas e regulamentos, método de controlo da ação, feedback, e de avaliação de resultados; definição da quantidade de monitores, inventariação e recolha de meios pedagógicos e materiais necessários, definição dos orçamentos e custos gerais).
c) Implementação: a implementação da formação é levada a cabo por formadores e com recurso a determinados métodos ou técnicas, podem ser três os tipos de pessoas que podem dar a formação profissional (consultor profissional que trabalha individualmente ou para uma firma de consultoria, professores universitários, membros do *staff* da organização).

De acordo com de Oliveira Rocha (2010), ainda que normalmente as organizações optem por formadores internos quando se trata de mero treino, torna-se necessário recorrer a formadores externos da organização quando se pretende introduzir alterações de mentalidades ou mudança de comportamento.

Pode-se compreender que para melhor implementação das atividades nas instituições, é necessário transformar os talentos em capital humano, ou seja, formar os funcionários e transformá-los capazes responder às necessidades da coletividade e ao mercado e gerar resultados de valor financeiro, económico e social para a instituição, criando um ciclo contínuo.

Ainda de Oliveira Rocha (2010), escreve que a forma de estruturação da formação procura conjugar as necessidades individuais com as necessidades organizacionais; ao contrário do modelo em que os recursos humanos são vistos como como resultado do planeamento estratégico, na era do potencial competitivo, os recursos humanos passam a ser o centro da organização, constituindo o seu recurso fundamental.

Entende-se que cada organização deve definir o modelo de formação profissional que pretende oferecer aos funcionários de acordo com as necessidades e desafios previamente identificados. No caso, a orientação inicial é de caracter imprescindível para novos integrantes de uma organização, porque permite a socialização no novo posto de trabalho, com os meios de trabalho, o ambiente do trabalho e fazer a interface entre o trabalhador e a organização. Portanto, o desempenho dos funcionários pode aumentar o baixar em função do estado motivacional e do esforço individual, podendo influenciar nos objetivos da organização.

De acordo com Armando (2021), o desempenho pode ser entendido como contingência porque:

> O desempenho contingencial varia de pessoa para pessoa e pode depender da influência de uma série de fatores condicionantes, tais como: cultura e ambiente organizacionais, valor das recompensas e a perceção de que as recompensas dependem do esforço individual que a pessoa estiver disposta a realizar. Por sua vez o esforço individual depende das habilidades e capacidades da pessoa e de sua perceção do papel a ser desempenhado.

Para Neto (2014), o desempenho "é um conjunto de caraterísticas ou capacidades de comportamento e rendimento de um indivíduo, de uma organização ou grupo". da Rosa Lopes et al. (2018), considera o desempenho como sendo uma ferramenta de gestão, a avaliação de desempenho visa a contribuir como suporte aos líderes de uma organização, para conhecer os aspetos relevantes do "capital humano", além de poder ajudar a tomar as devidas decisões, que poderão sofrer impactos de forma relevante nos resultados pretendidos.

Em suma, para obter bom desempenho dos funcionários nas instituições, passa primeiramente pela perceção da cultura organizacional, em segundo, perceber como têm sido gerido as recompensas para os funcionários que mais se destacam em função das suas habilidades e atribuições.

Segundo Da Paixão (2021), gestão de desempenho é o processo de conduzir os funcionários para atingirem as metas e objetivos da organização através de suas habilidades técnicas e comportamentais. Propõe alinhar os esforços para que competências humanas possam gerar e sustentar competências organizacionais necessárias à consecução de objetivos estratégicos. Entretanto, deve haver critérios a serem estabelecidos no processo de avaliação de desempenho, dependendo do que se pretende avaliar e do foco dessa avaliação: o indivíduo, a organização, relação cidadão-sociedade, ou qualquer outro.

Os critérios devem ser mensuráveis e condicionados a um planeamento, de forma a evitar a subjetividade na avaliação, embora nem tudo seja mensurável, é necessário evitar a subjetividade no processo avaliativo de modo a garantir um processo justo que responda aos propósitos para os quais foram instituídos (Armando, 2021).

A gestão do desempenho na Administração Pública em Moçambique não é uma atividade simples, visto que é um processo que passa por observância de procedimentos diversos e tomada de decisões. Porém na Administração Pública, tal como em qualquer organização, os funcionários têm por si uma capacidade que lhe é peculiar. Entretanto, o seu desempenho pode depender da área de atuação em que foi colocado e ficar extremamente condicionado a uma só atividade, se não for observada a rotatividade dos funcionários.

Metodologia

Quanto aos procedimentos técnicos a pesquisa é exploratória, de natureza aplicada e a abordagem é qualitativa. O estudo visa proporcionar uma visão geral sobre as ações de formação profissional e desempenho dos funcionários públicos em Moçambique, caso da UniZambeze, período entre os anos 2018 a 2022 e encontrar soluções na gestão de desempenho. O recorte temporal representa período marcado por profundas reformas na função pública sobre os procedimentos de progressão e critérios de enquadramento na tabela salarial única (TSU), fato que gerou bastante questionamentos.

Para o funcionamento a Universidade Zambeze conta com funcionários do corpo docente, investigativo e corpo técnico administrativo. Para o estudo foram considerados como sujeitos da investigação funcionários do Corpo Técnico e Administrativo, num universo de 123 funcionários. A nossa amostra incidiu funcionários afetos na Secretaria-geral, Direção de Recursos Humanos, Direção de Administração de Património, Direção de Registo Académico, Direção de Administração e Finanças, e Unidade Gestora de Executora de Aquisições, alargado para os funcionários do corpo administrativo de duas faculdades, entre as carreiras de auxiliar, assistente técnico, técnico administrativo, técnico profissional, técnico superior N1, técnico superior de tecnologias de comunicação e informação N1, incluindo os diretores e chefes de departamento no sector de recursos humanos, totalizando 86 funcionários. O nível académico dos funcionários abrangidos pela pesquisa varia entre o elementar, básico, médio do Sistema Nacional de Educação, nível médio profissional, licenciatura, mestrado e doutoramento, escolhidos por representatividade entre funcionário do Corpo Técnico e Administrativo, e domínio da temática. Com efeito, a análise seguiu as técnicas de entrevista semiestruturada através de roteiro pré-definido e flexível, dirigida aos gestores da instituição e questionário qualitativo com perguntas abertas para explorar as motivações, sentimentos e experiências dos funcionários públicos (Cervo, Silva e Bervian, 2007).

O objecto de estudo centra-se na análise dos processos de formação dos funcionários públicos em Moçambique, através de entrevistas dirigidas aos gestores e questionários para os técnicos, procurou perceber o grau de participação dos funcionários nos programas de formação, tipos de cursos, compatibilidade com área de trabalho, e as mudanças de desempenho havidas após a formação. Os dados foram processados através de programas informáticos Microsoft word e excel, em tabelas e gráficos e posteriormente analisados para gerar as conclusões. A classificação de desempenho dos funcionários públicos em Moçambique é feita com base nos padrões da matriz que constam das fichas de classificação periódica, e varia de Mau (< 10 pontos), Regular (10-13 pontos), Bom (14-16) e Muito bom (17-18 pontos) e Excelente (19-20 pontos) constam nos processos individuais dos funcionários.

Resultados e Discussão

Formação Profissional para os funcionários do Corpo Técnico e Administrativo

Foi possível apurar que no período entre os anos de 2018 a 2022, 80% dos funcionários CTA foram submetidos a programas de formação profissional de curta duração nomeadamente: formação no pacote de informática na ótica de utilizador e *microsoft office* 360 para o uso de *e-mail* institucional, 2 técnicos foram formados na área de gestão de laboratórios, 3 técnicos formados em gestão de sistemas e redes na Universidade Aberta em Portugal, 1 técnico foi formado em canalização, 1 em mecânica-auto, e 1 em jardinagem."

Com isso, concluímos que a UniZambeze tem promovido cursos de formação profissional por forma a responder novas exigências, desafios, globalização, mudanças comportamentais dos cidadãos, reforço às condições de trabalho, melhoria das qualificações e desempenho dos funcionários, fazendo parte das prioridades da instituição. A formação profissional permite aos funcionários aprendem novos conhecimentos e ganhar habilidades para um contexto cada vez mais exigente no qual a inovação, a criatividade, a necessidade de mudança e a competitividade são constantes. Por isso, constitui assim uma oportunidade dos funcionários adquirirem competências conducentes à execução de atividade com qualidade, por isso, deve ser encarada como uma oportunidade para o desenvolvimento profissional (ANDIFOI 2010, citado por Nhamoneque, 2018, Chiavenato 2015).

Foi constatado ainda que no mesmo período em análise, 95% dos funcionários além de participarem em ações de formação profissional, frequentaram também cursos de formação conducentes ao grau académico, sendo: 46% para o grau de licenciatura, 43% mestrado, 3% doutoramento e 8% participaram em cursos para obtenção do ensino médio e profissional, conforme ilustra o gráfico abaixo representado:

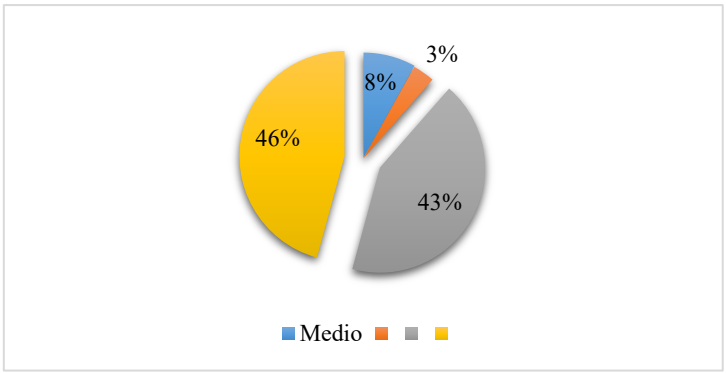

Figura 1. Funcionários em cursos de formação conducentes ao grau.
Fonte: Autor (2022).

Os dados ilustram que por um lado a UniZambeze reconhece a necessidade de implementar programas de formação como um processo contínuo, não só para a integração dos funcionários nas atividades vitais da instituição, mas também como um instrumento que permite a flexibilidade de adaptação dos funcionários perante novos desafios da atualidade. Por outro lado, os funcionários estão cada vez mais conscientes de que é vital aprender ao longo de toda a carreira, não apenas pelos avanços tecnológicos e desafios decorrentes das mudanças sociais com que tem de manter-se atualizados, mas porque devem sempre melhorar em algum aspeto, sejam as competências de uma determinada atividade, conhecimentos específicos ou potenciar o desempenho profissional.

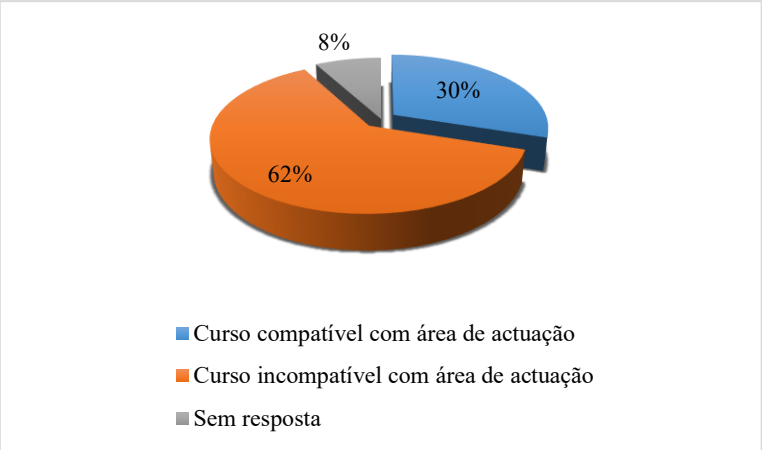

Figura 2. Compatibilidade do curso formação concluído, no sector de atuação do funcionário.
Fonte: Autor (2022).

O gráfico acima ilustra que da amostra de 42 funcionários inquiridos, 62% não foi formada ou capacitada em cursos que têm compatibilidade com as suas atividades que desempenham, apenas uma minoria relativa a 30% considera haver compatibilidade dos cursos de formação que frequentou, em relação às atividades que desempenham e 8% dos funcionários optaram por não responder a esta questão. Estes dados mostram um cenário de preocupação aos funcionários do CTA, pois, muitos que se encontram a exercer as atividades na instituição, não estão afetos em sectores que permitam explorar os conhecimentos específicos assimilados durante o processo de formação. O processo de retorno à formação deve habilitar o indivíduo desenvolver competências provocando assim estímulos diversos, que pode vir ou não a manifestar-se em mudanças no comportamento e elevar à qualidade o desempenho do indivíduo sem perder de vista os objectivos institucionais (IZAQUIERDO citado por Nhamoneque, 2018). A competência do indivíduo não se reduz a um conhecimento ou *know how* específico, deve haver um cruzamento com três eixos formados pela pessoa (sua biografia, socialização), pela sua formação educacional e pela sua experiência profissional (LE BOTERF 1995, citado por Nhamoneque, 2018). Portanto, não se pode frequentar cursos de formação pelas facilidades de ingresso ou influências de terceiros, deve haver conexão entre a socialização, profissão ou biografia dos funcionários para evitar desligamento total e dificuldades de enquadramento nas tarefas ou progressão na carreira.

Maior parte dos funcionários frequentou os cursos de Direito, Sociologia, Gestão de Recursos Humanos e Gestão. Isto, justifica-se pela falta de observância rigorosa de um plano de desenvolvimento de recursos humanos, que indica de forma clara as áreas prioritárias para o desenvolvimento da instituição. O Plano de Desenvolvimento de Recursos Humanos deve definir com clareza as formações de curto, médio e longo prazo, e adequar o ajustamento sólido e flexível dos Funcionários e Agentes do Estado, às necessidades do da instituição.

Análise do Quadro Legal e institucional da formação de recursos humanos na Função Pública.

Da análise feita ao quadro legal e institucional da formação de recursos humanos na Função Pública a partir da entrevista dirigida ao Diretor da Direção de Recursos Humanos na UniZambeze, foi possível apurar que:

> Existe, um Plano de Formação dos Funcionários e respetivo Regulamento, direcionado aos cursos de graduação (Licenciatura, Mestrado, Doutoramento) e cursos profissionalizantes de curto prazo. O Plano de Formação tem como principal objetivo de elevar o nível académico dos funcionários, habilitando-os para novos desafios, concretização da missão da instituição. Enquanto o Regulamento de Formação dos Funcionários permite estabelecer critérios de incentivo na formação dos funcionários, que passa por atribuição de isenção no pagamento de propinas e taxas de matrículas entre outros, aos funcionários que frequentam cursos na UniZambeze, no período pós-laboral. Para os que frequentam os cursos do período laboral, beneficiam de uma bolsa de estudos.

Foi possível apurar ainda que na UniZambeze os Planos de Formação Profissionalizante de curto prazo são elaborados especificamente com o objetivo de "orientar e acompanhar os funcionários através formação na

prestação dos serviços, dinamizar a utilização de novas tecnologias de informação, e melhorar as competências e diminuir o risco do absentismo. Porém, o plano não tem sido implementado a 100%, por falta de cabimento orçamental.

Na Administração Pública moçambicana o quadro legal e institucional em relação a formação de recursos humanos está previsto nos Estatutos Geral dos Funcionários e Agentes do Estado (EGFAE) aprovados pela Lei nº. 10/2017, de 1 de Agosto (Conselho de Ministros, 2017), e o respetivo regulamento Decreto n.º 28/2022 (Conselho de Ministros, 2022), de 9 de Junho e pela legislação específica da instituição. A necessidade de submissão de funcionários à formação é formalmente determinada através do Sistema de Gestão de Desempenho da Administração Pública (SIGEDAP), estabelecido pelo Decreto n° 55/2009 de 12 de Outubro (Conselho de Ministros, 2009). O SIGEDAP tem como objetivos:

> Identificar as necessidades de formação e desenvolvimento profissional adequadas à melhoria do desempenho dos funcionários e agentes do Estado″ (artigo 3). Serve também como um instrumento para avaliação do aproveitamento dos funcionários em programas de formação, das competências reveladas após a formação.

Segundo o disposto na Lei nº. 10/2017, de 1 de Agosto EGFAE, "os funcionários e Agentes do Estado desenvolvem através de um processo de formação e aperfeiçoamento as suas qualidades técnico-profissionais " (artigo 67).

Observado o Decreto n.º 28/2022, que Aprova o Regulamento do Estatuto Geral dos Funcionários e Agentes do Estado **(**REGFAE), estabelece que:

> A formação e aperfeiçoamento profissional são orientados para a capacitação, especialização e requalificação dos funcionários promovendo a eficiência e eficácia dos serviços. E que a formação se destina a capacitar os funcionários e agentes do Estado para melhorar o desempenho de suas atividades no sector ou ao desempenho de funções de direção, chefia e confiança.

Nota-se que os regulamentos internos da UniZambeze se adequam a legislação em vigor na Função Pública, no que diz respeito a formação de recursos humanos, por forma a responder com a Estratégia Global da Reforma do Sector Publico em Moçambique, visto que os planos de formação nos cursos de formação profissional de curto prazo, e cursos de formação conducentes ao grau, permitem a adequação do funcionamento da instituição aos desafios internos e externos.

Avaliação do desempenho dos funcionários após a formação

Na Administração Pública moçambicana, utiliza-se para avaliação de desempenho, o Sistema de Gestão de Desempenho (SIGEDAP) com objetivos de:

> Avaliar o desempenho individual dos funcionários e agentes do Estado, tendo em vista promover a excelência e a melhoria contínua dos serviços prestados aos cidadãos; melhorar o desempenho individual e a qualidade dos serviços prestados pela Administração Pública; elevar o comprometimento e o desenvolvimento das competências dos funcionários e agentes do Estado; contribuir para o desenvolvimento da Administração Pública e para a profissionalização dos funcionários e agentes do Estado; reconhecer e distinguir os funcionários e agentes do Estado pelo desempenho e mérito demonstrados na execução das suas atividades; identificar as necessidades de formação e desenvolvimento profissional adequadas à melhoria do desempenho dos funcionários e agentes do Estado; permitir a tomada de decisões relativas a nomeação, promoção, mobilidade, renovação de contrato, premiações, distinções e punições de acordo com a competência e o mérito demonstrados; e fortalecer as competências de liderança e de gestão.

Foi possível apurar que após a formação dos funcionários CTA, na UniZambeze é difícil uma análise rigorosa do processo de formação com o desempenho do funcionário, sobretudo aos cursos conducentes ao grau, pelo facto de haver funcionários que por iniciativa própria, frequentam cursos que não são compatíveis com as funções que desempenham nos respetivos setores. A avaliação de desempenho passa pela definição dos resultados esperados com base no planeamento estratégico da instituição e medição do grau de cumprimento dos objectivos previamente traçados por uma área ou instituição, (Armando 2021). A dificuldade para aferir as mudanças de desempenho dos funcionários após a formação, representa

fragilidades nas políticas institucionais de formação dos funcionários e falta de clareza dos resultados esperados após a formação. Por isso, compete aos gestores fazer um diagnóstico rigoroso e definir as exigências do sector, as competências a serem desenvolvidas e resultados esperados dos funcionários para permitir aferir as mudanças de desempenho após a formação. Porém, podemos afirmar que o processo de formação do CTA, para além de contribuir para a maturidade dos funcionários como indivíduos, a obtenção do grau académico é um indicador relevante para o desenvolvimento profissional na Função Pública, na medida em que permite a mudança de carreira e ascensão para exercer funções mais complexas.

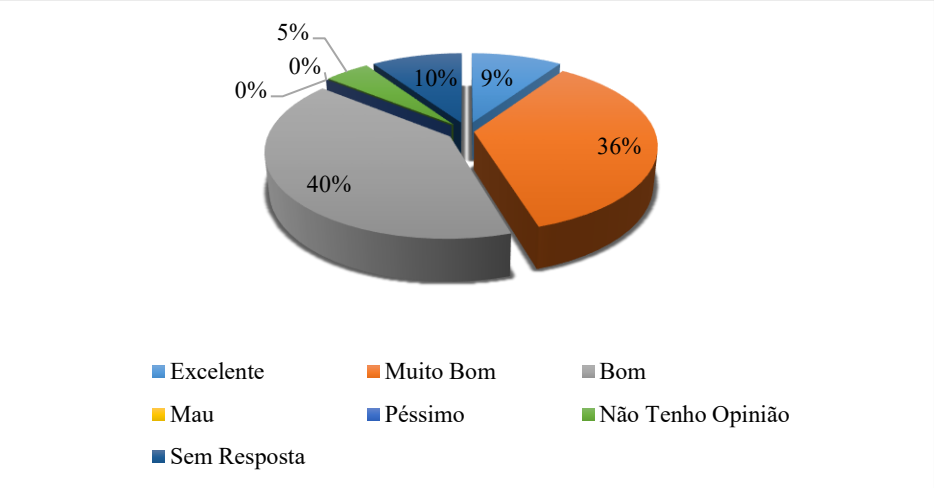

Figura 3. Avaliação do desempenho dos funcionários após a formação.
Fonte: Autor (2022).

O gráfico mostra que a avaliação do desempenho dos funcionários no período em analise, varia entre BOM 40% dos funcionários, MUITO BOM 36% dos funcionários e EXCELENTE 9%, e os restantes 15% optaram de abster-se de responder a questão. Entretanto, não se constatou na fixa de classificação a existência de um indicador claro, nem outro instrumento com indicadores que permitam fazer o acompanhamento e avaliação do desempenho dos funcionários após a formação. A elevada percentagem de funcionários com BOM desempenho pode nos conduzir a uma conclusão que a formação profissional dos funcionários, permite a aquisição de competências de modo a desempenhar as suas atividades com eficácia, eficiência, segurança e satisfação. Porém, embora seja reduzida a percentagem dos funcionários que se abstiveram de responder a questão, pode ser que os funcionários não sabem se tiveram um BOM melhoraram o seu desempenho apos a formação. Assim, podemos notou-se que a falta de indicadores claros de acompanhamento e avaliação de desempenho do funcionário após a formação, não permite aferir com exatidão a evolução dos funcionários após a formação (Armando, 2021).

Considerações Finais

A pesquisa analisou as ações de formação profissional e desempenho dos funcionários públicos em Moçambique, caso da UniZambeze, para perceber de que modo os cursos de formação profissional dos funcionários do CTA contribuem para melhoria do desempenho profissional, e chegou-se a conclusão que anualmente os funcionários são submetidos a cursos de formação profissional e cursos conducentes ao grau, por forma a responder novas exigências, desafios, globalização, mudanças comportamentais dos cidadãos, reforço às condições de trabalho, melhoria das qualificações e desempenho dos funcionários. Por outro lado, os funcionários estão cada vez mais conscientes da importância de aprender ao longo de toda a carreira, não apenas para corresponder aos avanços tecnológicos, mas porque percebem da necessidade de melhorar a cada dia em algum aspeto, seja as competências de uma determinada atividade, conhecimentos específicos ou potenciar o desempenho profissional.

Constatou-se ainda que maior parte dos funcionários que frequentam cursos de formação conducente ao grau, não observam rigorosamente o plano de formação institucional, por essa razão, há dificuldades de enquadramento após a formação nas áreas em que estes atuam.

No que diz respeito a legislação em vigor na Administração Pública em Moçambique, a UniZambeze possui planos de formação de funcionários em cursos profissionalizantes a curto prazo, e cursos de formação

conducentes ao grau, que permitem a adequação do funcionamento da instituição à Estratégia Global da Reforma do Sector Público. Entretanto, pode questionar-se sobre os critérios de selecção dos candidatos, os programas de formação e conteúdos temáticos a serem oferecidos aos funcionários se garantem mudanças de comportamento e melhoria do desempenho profissional dos mesmos.

Conforme ficou constatado, na Administração Pública em Moçambique a avaliação de desempenho é feita com base em fichas de avaliação de desempenho, com critérios previamente definidos, mas que não permitem fazer a avaliação de desempenho dos funcionários após a formação. Por isso, é difícil relacionar o processo de formação com o desempenho do funcionário, sobretudo aos cursos conducentes ao grau. Contudo, a conclusão de um curso de formação profissional ou obtenção de um grau académico dos funcionários públicos em moçambique, além de contribuir para a maturidade dos funcionários como indivíduos, é um indicador crucial para o desenvolvimento na carreira profissional, aumento do rendimento mensal, facto que afeta o crescimento de auto-estima, motivação e consequentemente melhoria de desempenho do trabalho. O fato da participação dos funcionários públicos nos programas de formação movidos pelos benefícios pessoais, pode levantar a problemática sobre os salários e benefícios sociais oferecidos aos funcionários públicos, se satisfazem ou não as necessidades básicas face ao custo de vida em Moçambique comparado com as instituições privadas.

Apesar de constatar-se a necessidade de observância rigorosa dos planos de formação e avaliação do desempenho dos funcionários pós-formação, os dados indicaram que a formação profissional dos funcionários do CTA contribuiu no seu desenvolvimento profissional e como consequência no seu desempenho, Assim, confirma-se a hipótese que indica a formação profissional dos funcionários pode contribuir de forma significativa e positiva para melhoria do seu desempenho profissional, bem como, o exercício de funções de acordo com sua formação.

Sugestões

Para melhorar o processo de formação profissional dos funcionários CTA e promover a eficiência e eficácia sugere-se o seguinte:

- Identificar as necessidades de formação de acordo com as exigências laborais e de desenvolvimento institucional;
- Definir critérios de avaliação do desempenho dos funcionários viáveis para comparar o desempenho do funcionário após formação.
- Realizar estudo sobre o impacto da implementação do novo sistema de carreiras na função pública em moçambique através da Tabela Salarial Única (TSU).

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Exploring university mathematics professors' perceptions and use of GenAI: a conceptual fields approach

Percepciones y el uso de IAGen en profesores universitarios de matemáticas desde Campos Conceptuales

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Abstract

Generative Artificial Intelligence (GenAI) is rapidly transforming higher education, challenging traditional pedagogical norms, and prompting a re-evaluation of teaching and learning practices. This study analyzes the operational invariants guiding university mathematics professors' action schemes when interacting with GenAI, using the Theory of Conceptual Fields (TCF) as a theoretical framework. Semi-structured interviews were conducted with ten active university mathematics professors, focusing on the eight dimensions of Technological Pedagogical Content Knowledge (TPACK). Transcriptions were analyzed to infer enacted theorems (ETs), classified into eight thematic categories: general functionality, prompt construction, knowledge validation, academic applications, ethics and regulation, relationship with teaching and learning, teacher knowledge and use, and limitations and risks. Results revealed a

Resumen

La Inteligencia Artificial Generativa (GenAI) está transformando rápidamente la educación superior, desafiando las normas pedagógicas tradicionales y motivando una reevaluación de las prácticas de enseñanza y aprendizaje. Este estudio analiza los invariantes operacionales que guían los esquemas de acción de los profesores universitarios de matemáticas al interactuar con la GenAI, utilizando como marco teórico la Teoría de los Campos Conceptuales (TCC). Se realizaron entrevistas semiestructuradas a diez profesores universitarios activos de matemáticas, centradas en las ocho dimensiones del Conocimiento Tecnológico Pedagógico del Contenido (TPACK). Las transcripciones fueron analizadas para inferir teoremas en acto (ETs), los cuales se clasificaron en ocho categorías temáticas: funcionalidad general, construcción de prompts, validación del conocimiento, aplicaciones académicas, ética y regulación, relación con la enseñanza y el

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predominantly pragmatic usage scheme, with GenAI perceived as a search engine, process optimizer, and code generator. However, contradictory ETs indicate that the conceptual field is still under construction. Teachers primarily use GenAI for text editing, content generation, and idea organization, but its direct classroom use remains limited. Epistemological ambivalence exists regarding Gen's authority, with concerns about errors. Ethical and regulatory issues are not yet central. Findings highlight the need for critical, reflective, and context-sensitive appropriation of GenAI in university mathematics education, supported by professional development and institutional policy.

Keywords: Artificial intelligence, Educational technology, Teacher education, Higher education, Cognition, Conceptual Fields.

aprendizaje, conocimiento y uso docente, y limitaciones y riesgos. Los resultados revelaron un esquema de uso predominantemente pragmático, con GenAI percibida como un motor de búsqueda, optimizador de procesos y generador de código. Sin embargo, los ETs contradictorios indican que el campo conceptual aún está en construcción. Los profesores emplean principalmente la GenAI para la edición de textos, generación de contenidos y organización de ideas, pero su uso directo en el aula sigue siendo limitado. Existe una ambivalencia epistemológica respecto a la confiabilidad de la GenAI, con preocupaciones sobre su propensión a cometer errores. Los marcos éticos y regulatorios aún no son centrales en el campo conceptual. Los hallazgos destacan la necesidad de una apropiación crítica, reflexiva y sensible al contexto de la GenAI en la educación universitaria en matemáticas, apoyada por el desarrollo profesional docente y la política institucional.

Palabras claves: Inteligencia artificial, Tecnología educativa, Formación docente, Educación superior, Cognición, Campos Conceptuales.

Introduction

The rapid evolution of GenAI models such as ChatGPT, Gemini, and Llama is transforming higher education by altering teacher–student–knowledge dynamics and opening new research lines (Silgado-Tuñón & López-Flores, 2025a). In this sense, generative systems not only facilitate problem solving, but also propose new forms of interaction with knowledge (Silgado-Tuñón & López-Flores, 2025b). Studies show that these chatbots can solve mathematical problems (Kang, 2024; Kwon et al., 2023; Sureda et al., 2024; Parra et al., 2024b; Corica et al., 2024) and adapt learning strategies (Lee et al., 2023), although their performance declines when using specific theoretical frameworks such as Brousseau's Theory of Didactical Situations (Parra et al., 2024a). The ability of these LLMs to design tasks, generate explanations, and propose solutions raises challenges concerning the reliability and rigor of content. Thus, integrating GenAI requires not only adoption but also a broader pedagogical and ethical re-evaluation. It affects curriculum design, use as a didactic resource, assessment methods, and university policies (Larico-Hanco, 2024).

Recent studies reveal that professors express contradictory beliefs about GenAI: while most are familiar with these tools and 72% have experimented with them (Ruediger et al., 2024), few feel confident about their effective incorporation into teaching. Only a minority (14–18%) felt confident or understood its pedagogical applications, while many (38%) expressed little or no confidence. No individual use case has been established, suggesting that adoption is more exploratory than fully integrated.

Professors highlight GenAI's usefulness for developing learning materials, creating assessments, personalizing content, supporting professional development, analyzing data, and assisting with administrative tasks (Alshamy et al., 2025; Larico-Hanco, 2024; Ruediger et al., 2024). Some studies suggest that GenAI can enhance academic performance, foster critical and creative thinking, and improve students' understanding and production of texts (Larico-Hanco 2024). The emphasis on efficiency and content generation indicates that professors primarily perceive GenAI as a productivity tool for their existing work. While personalization is mentioned, the perceived benefits revolve around automation or assistance with labour-intensive tasks, which could free up time for more complex teaching activities but also brings the risk of reducing the human element in certain processes if not managed carefully.

Despite these benefits, teachers voice stronger concerns than students, particularly about academic misconduct such as plagiarism (Alshamy et al., 2025; Larico-Hanco, 2024). They fear excessive dependence that may erode critical thinking, creativity, and lead to superficial learning (Alshamy et al.,

2025; Cabellos et al., 2024). Other challenges include biased or inaccurate information, unreliable citations, and the difficulty of distinguishing AI-generated from human work (Larico-Hanco, 2024). Some educators, especially in the humanities, worry that GenAI undermines trust in teaching practices, while others point to risks of widening inequality (Ruediger et al., 2024). Overall, integrity and critical thinking are perceived as core threats, explaining why 42% of instructors prohibit student use (Ruediger et al., 2024).

Objective of the study

The main objective of this study is to analyze the operational invariants that guide the action schemes of university mathematics teachers when interacting with GenAI, to inform adoption strategies and institutional policies.

This study analyzes the operational invariants guiding teachers' action schemes with GenAI, aiming to inform adoption strategies and institutional policies.

Theoretical Framework

This study adopts Vergnaud's Theory of Conceptual Fields (1990, 2013), which views knowledge as schemes constructed through action. We drew on two of Vergnaud's four definitions of scheme.

Functional definition. A scheme is an invariant organization of behaviour in response to a family of situations.

Structural definition. The scheme is composed of (a) goals that guide the activity, (b) rules of action and control, (c) systems of representation, and (d) operational invariants.

Operational invariants include both operative concepts and operative theorems (OT). The former refers to relevant categories, evaluated not by their truth but by their usefulness in guiding action; the latter are propositions assumed as true during action. While both give meaning to the scheme, they differ from scientific concepts and theorems, which are explicit and subject to debate, whereas operational invariants usually remain implicit, forming the submerged part of the conceptual 'iceberg.

Thus, the decisions a teacher makes in a didactic situation depend on the scheme activated, and on the operative concepts and theorems available to them. These invariants make it possible to select relevant information and, according to the goal, deduce the most appropriate rules of action (Vergnaud, 1990). In other words, they render the scheme operative.

When operative concepts and theorems are verbalized, they are transformed into objects for reflection, whose validity can be discussed, thus approaching scientific knowledge. Conversely, all formalized knowledge originates from these operational invariants, which are made explicit over time. However, formalized knowledge constitutes only a fraction of the knowledge that can be put into words. Vergnaud (2007a, 2007b) distinguishes two forms of knowledge: operative (acting effectively) and predicative (describing objects and relations).

This study examines professors' explicit responses, thus focusing on the predicative dimension of knowledge, which offers only a partial view of the operative knowledge mobilized in teaching.

Methodology

We conducted semi-structured interviews with ten university professors from Mathematics, Physics, Engineering, and Science and Technology of Light and Matter (LUMAT) at a Mexican public university. All held doctorates and taught mathematics across different programs. The group included graduates in mathematics, physics, economics, agronomy, and computer systems.

Although their undergraduate backgrounds vary, all participants share a common professional denominator: they actively teach mathematics at the university level. This shared teaching practice legitimizes the focus of the study on their mathematical action schemes, since their daily instructional decisions and interactions are framed within the discipline of mathematics regardless of their original field of training.

Interviews lasted about 50 minutes and explored TPACK dimensions (Mishra & Koehler, 2006; Mishra et al., 2023), focusing on professors' perceptions and uses of GenAI in mathematics teaching. Questions addressed familiarity with GenAI, prompt construction, applications in teaching and research, curriculum design, and perceptions of benefits, risks, and biases.

Interviews were transcribed with Whisper, organized with ChatGPT, and securely stored and processed in cloud services.

Table 1 illustrates how episodes were constructed and how enacted theorems (ET) were inferred. The excerpt corresponds to Interviewee P1, a professor with 12 years of experience and advanced training in mathematics. His statements on the use of GenAI in the classroom were coded into ETs, such as *'GenAI works as a search engine'* or '*GenAI is an image generator*.' Each episode (E) denotes a speaking turn, and the corresponding ET reflects the researcher's analytical inference from the professor's responses.

Table 1.
Example excerpt corresponding to Interviewee P1.

Interviewer (E. 11): What role do you think artificial intelligence could play?	Interviewee (E. 12): *I think it can be used to verify results or calculations* (TA.5; TA.8). *I also think it is useful to search for information* (TA.2). Replace? I don't know. I think if you ask artificial intelligence something, it will probably give you an answer.	ET.5: GenAI provides correct results. ET.2: GenAI works as a search engine. ET.8: GenAI has the authority of a book or a teacher.
Interviewer (E. 21): Do you have any specific experience using artificial intelligence to improve teaching?	Interviewee (E. 22): Yes. As I mentioned, *I have used AI-generated images* (TA.7) *that helped me illustrate mathematical concepts. That part was useful to me. And the codes it generates have also helped me a lot* (TA.6).	ET.7: GenAI is an image generator. ET.6: GenAI is a generator of simple correct codes.

After coding all interviews, the ETs were classified into eight thematic categories: (1) general functionality, (2) prompt construction, (3) authority and validation, (4) academic and educational applications, (5) ethics and regulation, (6) teaching and learning relationships, (7) teacher knowledge and use, and (8) limitations and risks. For each ET, we recorded its number, description, frequency, validity, and category. The following section presents the tables organized by category.

Results and Discussion

In the first category, related to the general functionality of GenAI, the enacted theorems concerning what GenAI is and what it can do are grouped together; this category includes enacted theorems linked to its operational definition, technical capabilities, and general limitations.

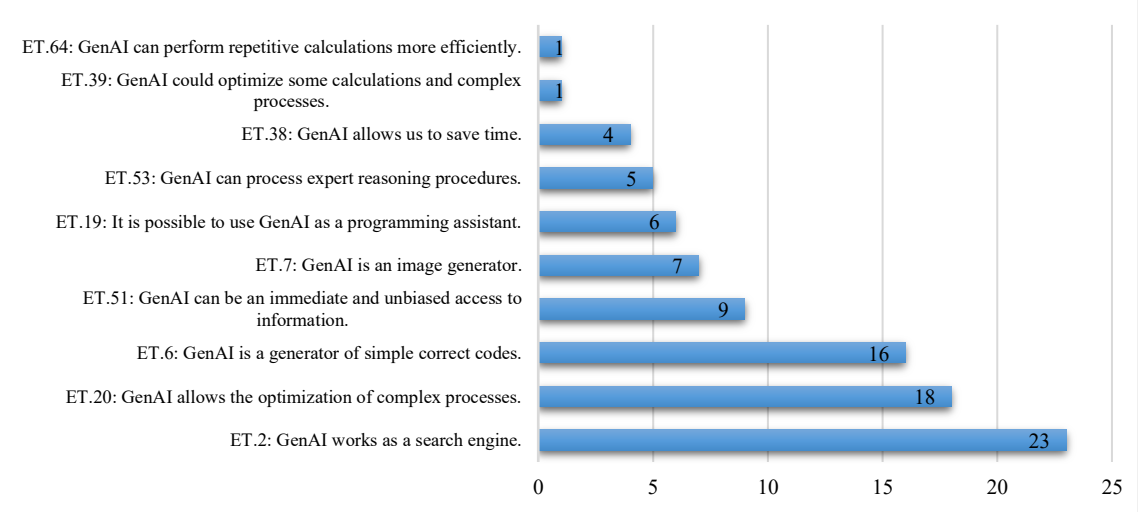

Figure 1. Category 1.

The results reveal that, within the conceptual field of university mathematics professors, a pragmatic usage scheme predominates. A core group of enacted theorems guides interaction with the tool: ET.2 (*GenAI works as a search engine*), ET.20 (*GenAI allows the optimization of complex processes*), and ET.6 (*GenAI generates simple correct codes*). These invariants frame GenAI as a rapid source of information, a resource for refining procedures, and a support for basic code production. From the perspective of the Theory of Conceptual Fields, this hierarchy reflects professional practices—information search, algorithmic modelling, and code prototyping—that have crystallized into stable schemes.

At the same time, the validity of these theorems is contested. ET.2 is problematic because AI responses are not equivalent to those of a search engine, and ET.6 requires caution since generated codes are not always correct. This tension highlights the need to qualify the authority of pragmatic uses.

Less frequent theorems point to incipient expansions. ET.51 describes GenAI as unbiased information access, ET.7 as an image generator, and ET.19 and ET.53 as a programming assistant and processor of reasoning. These open the possibility of collaborative or epistemic roles. By contrast, ET.38, ET.39, and ET.64, which link GenAI to numerical automation, remain marginal, reflecting the tool's current limitations in mathematical reasoning (Sureda & Otero, 2025).

Overall, this category shows a conceptual field still under construction: pragmatic uses dominate, while explorations into more advanced or epistemic applications are emerging but not yet consolidated. For the second category, relating to the use and construction of Prompts, the enacted theorems concerning how to interact with GenAI are grouped; Figure 2 presents the frequency of the enacted theorems in this category.

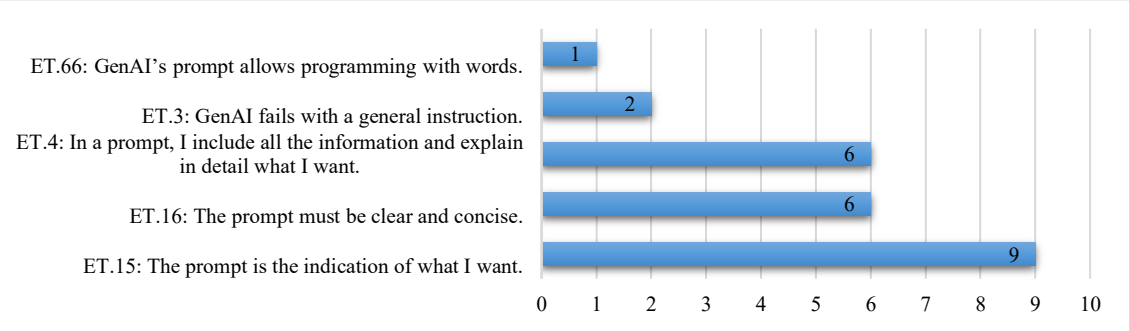

Figure 2. Category 2.

The data show that, within the conceptual field of prompt construction, teachers have stabilized a scheme centered on clarity of objectives and syntactic precision. The most frequently enacted theorem, ET.15 (*The prompt is the indication of what I want*), operates as an invariant guiding activity: the prompt is conceived as the tool that channels GenAI's action. Two additional theorems highlight a central tension. ET.16 (*The prompt must be clear and concise*) reflects a search-engine logic, where brevity ensures results, while ET.4 (*The prompt must include all information and detail*) aligns with conversational interaction with GenAI and points to the need for greater specificity. From the perspective of the Theory of Conceptual Fields, these theorems define the tacit rules of the main scheme and reflect recurrent situations of interaction that ensure its viability.

Less frequent theorems expand this field. ET.3 (*GenAI fails with a general instruction*) acts as a metacondition of validity, underscoring the importance of specificity and triggering restructuring when responses lack relevance. ET.66 (*Prompting is programming with words*) suggests an exploratory view of prompt syntax as a form of high-level code, pointing toward more formalized practices of "linguistic programming."

Overall, this category reveals a diversity of conceptions regarding prompt construction, ranging from minimal clarity to exhaustive detail. These distinctions carry direct implications for the communicative and pedagogical effectiveness of GenAI in educational contexts.

Category 3, called Authority and Validation of Knowledge, relates to the trust, validity, and verification of the responses provided by different GenAI tools. This category encompasses representations regarding the

reliability of the generated information, the epistemological authority attributed to the tool, and the demands for critical judgment required for its educational application.

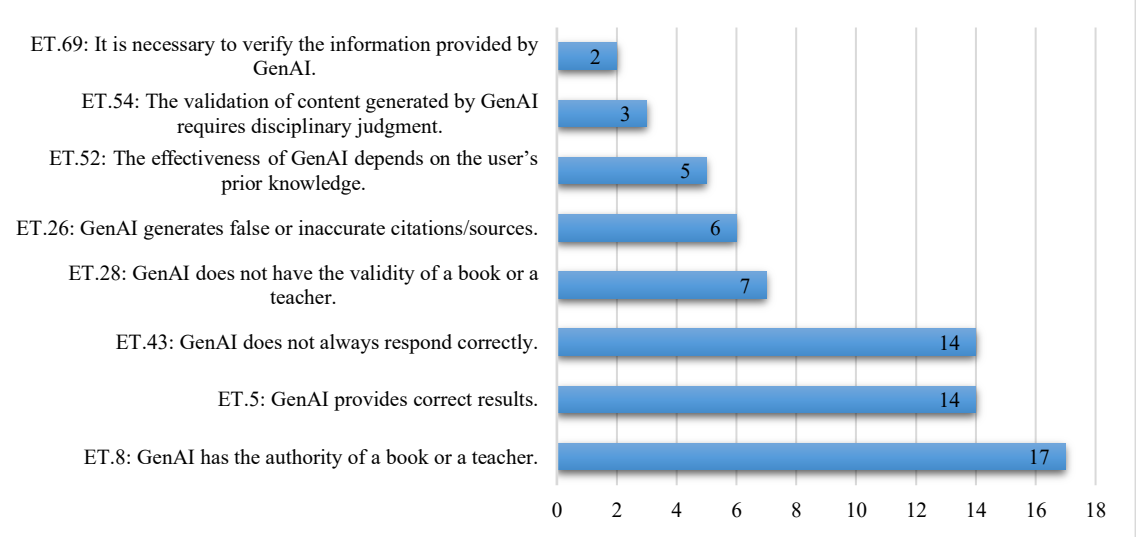

Figure 3. Category 3.

The results show a clear tension in the conceptual field of university mathematics professors regarding the epistemological status of GenAI. The most frequent enacted theorems are ET.8 (*GenAI has the authority of a book or teacher*), ET.5 (*GenAI provides correct results*), and ET.43 (*GenAI does not always respond correctly*). This contradiction reflects conceptual ambivalence: while the tool is perceived as a reliable source comparable to disciplinary knowledge, its propensity for errors is also recognized.

From the perspective of the Theory of Conceptual Fields, this can be read as the coexistence of contradictory yet un-stabilized schemes. The strong presence of ET.8 and ET.5 suggests a process of **naturalizing GenAI's authority**, possibly encouraged by the fluency with which it presents answers. In contrast, ET.43 functions as a **control mechanism**, questioning that authority and fostering a more reflective stance. This unstable balance between trust and suspicion indicates a conceptual field still in reorganization.

Other theorems reinforce the need for validation. ET.28 (*GenAI does not have the validity of a book or teacher*) and ET.26 (*GenAI generates false or inaccurate references*) respond directly to technical limitations such as hallucinations and fabricated sources. Less frequent theorems—ET.52 (*Effectiveness depends on the user's prior knowledge*), ET.54 (*Validation requires disciplinary judgment*), and ET.69 (*Information must be verified*)—emphasize the teacher's role as epistemologically active agent, responsible for comparing, correcting, and contextualizing outputs.

Overall, this category reveals a conceptual field **in dispute**, where naive representations of GenAI's authority coexist with critical stances demanding verification and expert judgment. Effective integration in university classrooms appears to depend on moving from automatic trust toward a reflective, epistemologically grounded use.

Category 4: Academic and Educational Applications pertains to the use of GenAI by professors in both their personal and professional activities. This category encompasses representations concerning text editing, the generation of teaching materials, idea organization, lesson planning, and assistance with evaluation tasks.

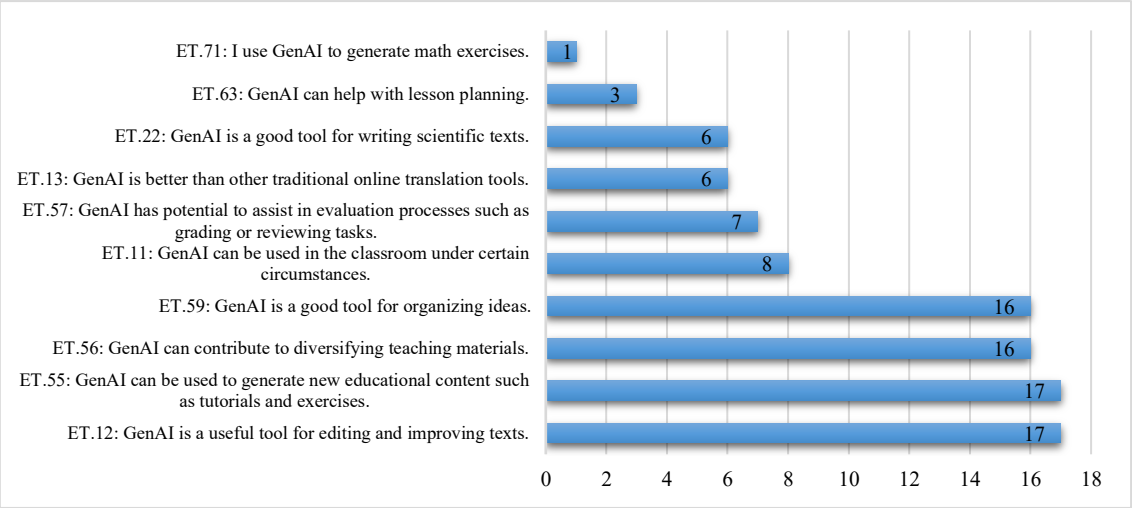

Figure 4. Category 4.

The results indicate that university mathematics professors attribute multiple academic support functions to GenAI. The most frequently enacted theorems are ET.12 (*GenAI is useful for editing and improving texts*) and ET.55 (*GenAI can generate new educational content such as tutorials and exercises*), closely followed by ET.56 (*GenAI diversifies teaching materials*) and ET.59 (*GenAI helps organize ideas*). Together, these theorems frame GenAI as a versatile assistant for text production and content structuring. From the perspective of the Theory of Conceptual Fields, they constitute a stabilized usage schema centered on productivity and efficiency. GenAI is not restricted to classroom application but extends to preparation and organizational tasks, functioning as an extension of teaching work.

Other theorems broaden this field. ET.11 suggests limited classroom use, while ET.57 (*GenAI assists in evaluation, e.g., grading or reviewing*) and ET.13 (*GenAI improves on traditional translation tools*) reflect its adoption for automated or technical tasks, reinforcing its utility in academic management.

More specialized theorems indicate exploratory moves toward discipline-specific use. ET.22 frames GenAI as a tool for scientific writing, ET.63 as support for lesson planning, and ET.71 as a generator of math exercises. These applications demand greater intellectual rigor and pedagogical contextualization, but their low frequency suggests that this transition remains incipient.

Overall, this category depicts a conceptual field dominated by technical and organizational uses, focused on improving academic products and optimizing routine tasks. Signs of a more didactic and discipline-specific appropriation are present yet marginal. Consolidating GenAI as an effective ally in mathematics teaching will likely depend on expanding these advanced uses and critically integrating them into planning and assessment.

Category 5, related to Ethics, Regulation, and Plagiarism—referring to responsibility, appropriate use of GenAI, and the standards that should govern its use— gathers representations related to human supervision, regulatory frameworks, authorship of work, and misuse of the tool.

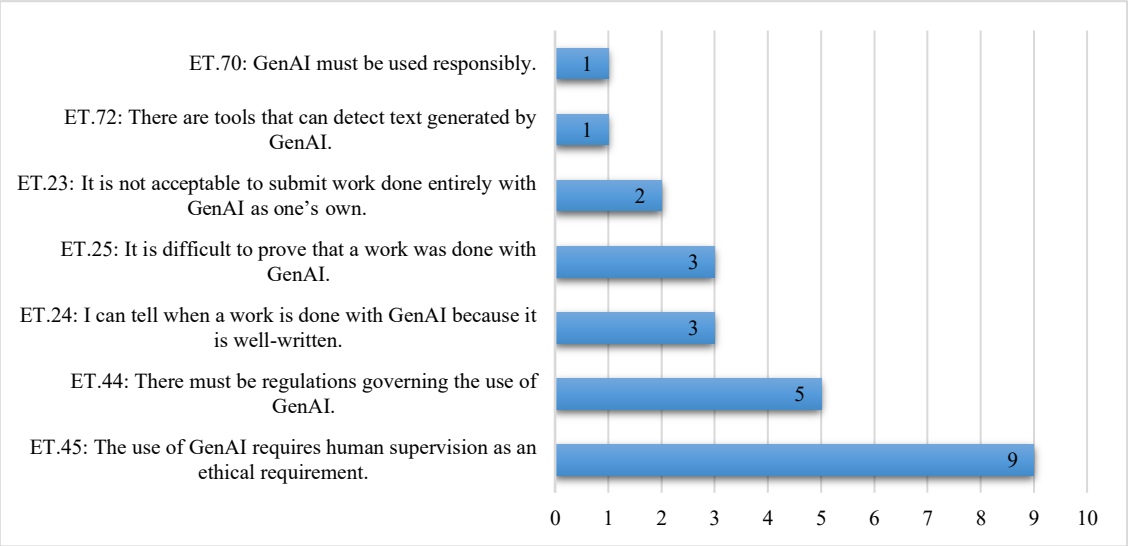

Figure 5. Category 5.

The results reveal an emerging, though still incipient, concern about the ethical use of GenAI in academia. The most frequent enacted theorems highlight that its use requires human supervision (ET.45) and must be governed by regulations (ET.44). Both indicate the perception that GenAI cannot be deployed outside an ethical and legal framework that ensures responsible use. From the perspective of the Theory of Conceptual Fields, these theorems represent regulatory invariants that remain under construction. Their low frequency compared to other categories shows that ethics is not yet central in professors' conceptual field, though it is beginning to gain relevance as a necessary component of pedagogical practice.

Other theorems focus on plagiarism. ET.24 (*I can tell when a paper was done with GenAI because it is written*) and ET.25 (*It is difficult to prove a paper was done with GenAI*) reveal tension between intuitive detection and the practical difficulty of verification. These highlight unresolved questions about authorship, assessment, and originality.

Less frequent theorems reinforce academic integrity, such as ET.23 (*It is not acceptable to submit a paper fully generated with GenAI*), ET.72 (*There are tools that can detect AI texts*), and ET.70 (*GenAI must be used responsibly*). Although rare, they indicate the emergence of an implicit regulatory framework where acknowledgment, moderation, and external control are considered necessary for legitimate use.

In summary, this category reflects an ethical awareness that is still peripheral but growing. Professors recognize the importance of norms and principles, yet these have not been consolidated as structural elements of their professional practice. Consolidation of this ethical dimension will depend on institutional regulation and pedagogical strategies that foster responsible, transparent, and critical use of GenAI.

Category 6, called Relationship with Teaching and Learning, relates to the effect of using GenAI in educational settings linked to the teaching and learning process. This category includes enacted theorems that address its integration as a didactic tool, its impact on conceptual and procedural understanding, and the transformation of the traditional roles of teachers and students.

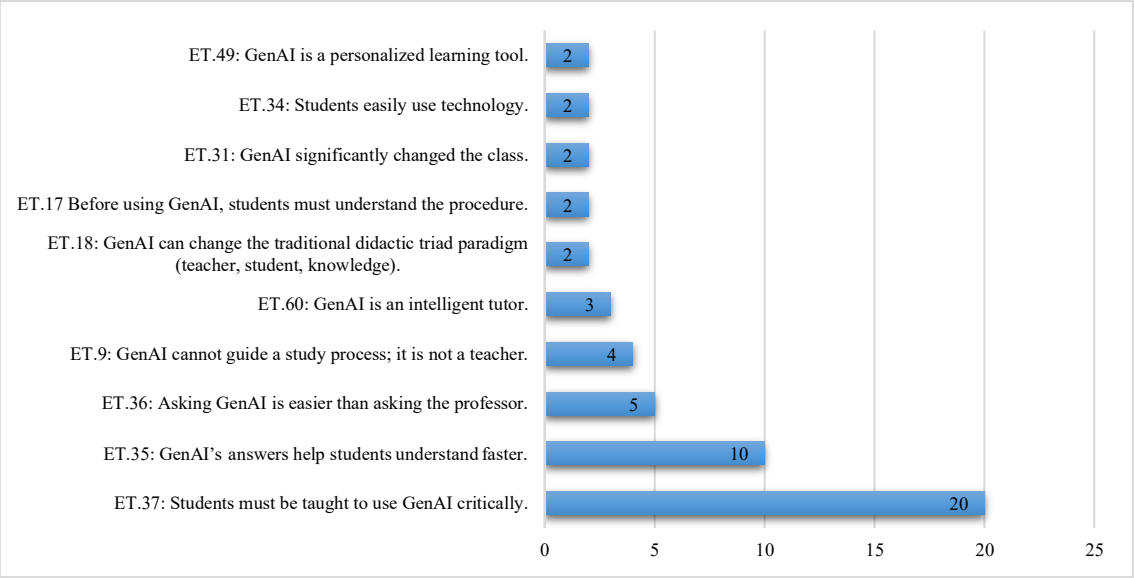

Figure 6. Category 6.

The results show a nuanced perception among university mathematics instructors regarding the incorporation of GenAI into teaching. The most frequently enacted theorem is ET.37 (*Students must be taught to use GenAI critically*), highlighting concern for developing critical literacy and avoiding unreflective dependence. This points to an emerging recognition that competencies for ethical and thoughtful use must be deliberately fostered.

Other theorems reveal positive yet ambivalent experiences. ET.35 (*GenAI's answers help students understand faster*) and ET.36 (*Asking GenAI is easier than asking the professor*) suggest enhanced comprehension but also raise questions about the devaluation of direct pedagogical relationships. This duality indicates a transformation in classroom communication, where GenAI begins to function as an accessible cognitive mediator.

Tensions also appear between GenAI as support and its inability to replace human mediation. ET.9 asserts that it cannot guide a study process, while ET.60 frames it as an intelligent tutor. Together, these positions underline that while GenAI can assist in specific tasks, it is not perceived as a substitute for sustained educational guidance.

Less frequent theorems—ET.18 (*GenAI may change the didactic triangle*), ET.17 (*Students should understand the procedure before using GenAI*), and ET.31 (*GenAI greatly changed the class*)—reflect early explorations of epistemological and methodological transformation, as well as conditions for valid didactic use. ET.34 (*Students use technology easily*) and ET.49 (*GenAI supports personalized learning*) reinforce perceptions of accessibility and adaptation, though still at an early stage.

Taking together, this category depicts a **transitional conceptual field**, where enthusiasm for efficiency and accessibility coexists with the need to construct a critical pedagogical framework to guide integration. From the perspective of the TCF, usage schemes remain heterogeneous but teaching students how to use GenAI critically emerging as a necessary component of mathematics education.

Category 7 relates to GenAI Knowledge and Use by Instructors, which groups ET concerning teachers' attitudes, experiences, and challenges. This category addresses aspects related to both the degree of technological adoption and the cognitive, emotional, or generational barriers mediating its integration into teaching practices.

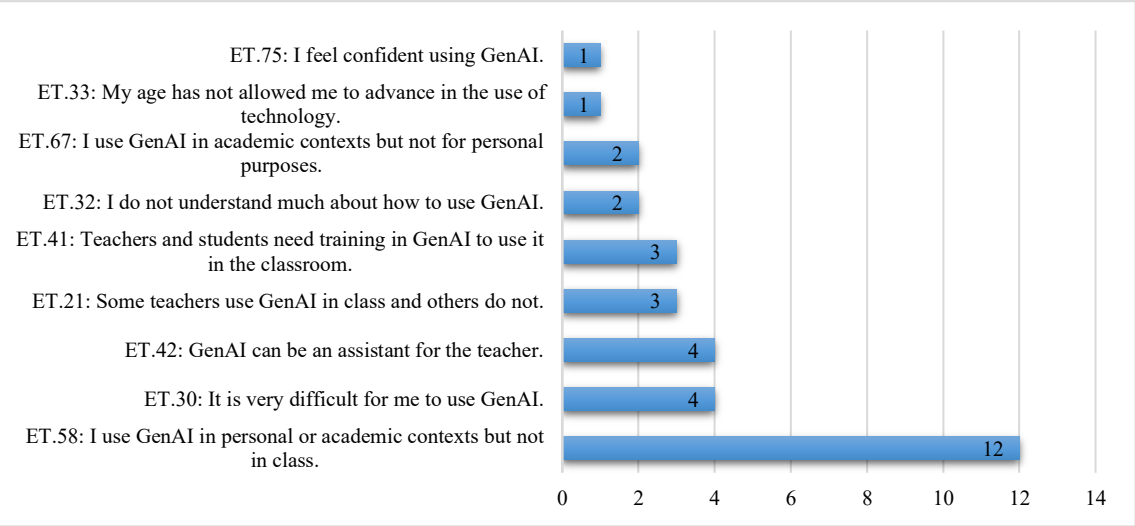

Figure 7. Category 7.

The results reveal an unequal and fragmented appropriation of GenAI among university mathematics faculty. The most frequent enacted theorem is ET.58 (*I use GenAI personally or academically but not in class*), which underscores the gap between private and pedagogical use. Although teachers recognize its potential, they face didactic, institutional, or epistemological barriers that limit integration into classroom practice.

Other theorems reflect ambivalence. ET.30 points to difficulties in using GenAI, while ET.42 highlights its value as an assistant for teaching work. This duality appears linked to varying levels of technological familiarity and the absence of training in pedagogical applications. ET.21 (*Some teachers use GenAI in class and others do not*) and ET.41 (*Teachers and students need training to use it effectively*) further emphasize the heterogeneity of adoption and the urgent need for professional development that promotes critical and context-sensitive appropriation.

Less frequent theorems reveal additional barriers. ET.32 (*I do not understand much about GenAI*), ET.67 (*I use it academically but not personally*), and ET.33 (*My age prevents me from advancing with technology*) point to cognitive, attitudinal, and generational limitations that create zones of resistance and insecurity. Addressing these requires institutional policies on digital inclusion. In contrast, ET.75 (*I feel confident using GenAI*) represents a minority of faculty who have advanced beyond the exploratory stage and achieved stable integration.

In summary, this category portrays an appropriation still in its early stages, where personal experiences disconnected from teaching, technological insecurity, and strong demands for training outweigh actual integration. From the perspective of the Theory of Conceptual Fields, usage schemes remain under construction, as individual and collective difficulties prevent the consolidation of shared operational invariants for systematic use.

Category 8, related to limitations and risks, groups together the enacted theorems related to errors, dependence, and problematic aspects of GenAI. This category gathers teacher representations that emphasize the cognitive, ethical, and functional boundaries of these technologies in education.

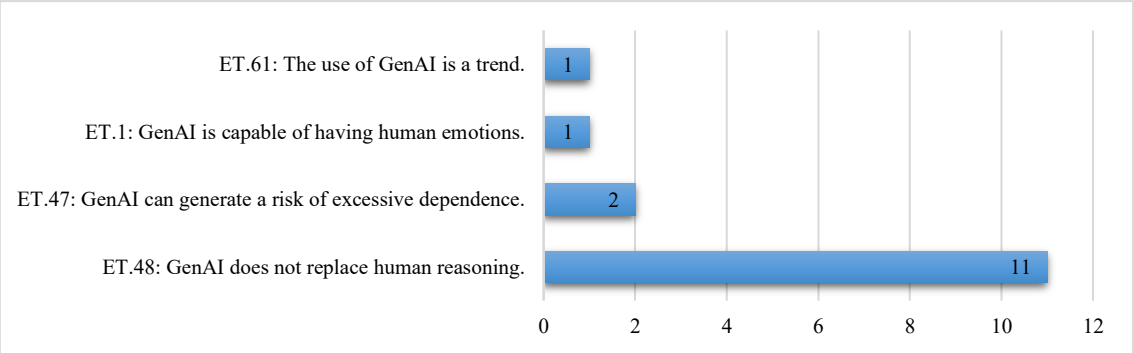

Figure 8. Category 8.

The results reveal that, although less frequently than in other categories, there is a clear conceptual core that identifies the epistemic boundaries of GenAI. The predominant enacted theorem is ET.48 (*GenAI does not replace human reasoning*), which synthesizes a critical stance among faculty: despite its technical potential, GenAI lacks the reflective, inferential, and metacognitive capacities inherent to human thought.

Its recurrence indicates that even frequent users remain aware of these limitations.

ET.47 (*GenAI can generate excessive dependence*) highlights concern about weakening autonomous thinking in teachers and students, raising risks of pedagogical de-professionalization and superficial learning.

Other theorems appear at the margins of the conceptual field. ET.1 (*GenAI is capable of human emotions*) reflects ontological confusion about its functioning, while ET.61 (*The use of GenAI is a trend*) reduces it to a passing fashion, potentially discouraging critical and sustained integration.

Together, these theorems indicate an incipient but firm framework that sets boundaries and anticipates risks. From the perspective of the Theory of Conceptual Fields, they operate as **defensive schemes** regulating responsible use. Although not yet a dominant core, their presence is essential to balance the utilitarian and enthusiastic views prevailing in other categories.

Taken together, the eight categories reveal that the conceptual field of university mathematics professors regarding GenAI is still in a **phase of construction and reorganization**. A pragmatic orientation dominates professors primarily using the tool as a search engine, process optimizer, and assistant for text and content production. These stabilized schemes reflect a strong focus on productivity and efficiency in academic work.

At the same time, other categories point to **tensions and contradictions** that limit homogeneous appropriation. On the one hand, there is a tendency to naturalize GenAI's authority, treating it as a reliable source; on the other, various theorems stress its fallibility and the need for verification. This ambivalence illustrates the coexistence of un-stabilized schemes where trust and suspicion are balanced uneasily.

The categories also show **incipient explorations** beyond routine uses personalized learning, class planning, evaluation support, scientific writing, or programming assistance. Although still marginal, these theorems suggest a potential broadening of the field toward pedagogical innovation and discipline-specific applications. At the same time, limitations and risks—excessive dependence, ethical dilemmas, and ontological confusions—are acknowledged, shaping defensive schemes that temper enthusiasm with caution.

Overall, the results portray a **fragmented and transitional field**, where pragmatic appropriation coexists with emerging critical awareness. From the perspective of the Theory of Conceptual Fields, this configuration indicates that operational invariants have not yet been crystallized into a shared and stable framework. Instead, teachers navigate between efficiency-driven practices, ethical and epistemological concerns, and the challenge of integrating GenAI into mathematics education in a reflective and pedagogically grounded way.

General Discussion

Across the eight categories, a clear dialectic emerges between pragmatic and epistemological dimensions. On one side, professors' predominant operational schemes reflect utilitarian uses of GenAI oriented toward productivity, optimization, and information retrieval. On the other, there is an emerging epistemic ambivalence that reveals reflective awareness about authority, validity, and ethical responsibility. This duality—between efficiency and critical caution—constitutes the core tension shaping teachers' conceptual field.

From the perspective of Vergnaud's Theory of Conceptual Fields, these results suggest that while pragmatic invariants (e.g., "*GenAI provides correct results*," "*GenAI works as a search engine*") have stabilized, epistemological and ethical invariants remain under construction. Teachers oscillate between trust and suspicion, adaptation and resistance, and their schemes evolve as they encounter new didactic and technological situations. Thus, the current conceptual field can be described as transitional: oriented toward practical benefit but increasingly open to epistemological and pedagogical reflection.

Limitations and Future Research

This study nevertheless presents limitations. The sample is limited to a specific group of mathematics professors, which restricts the generalizability of the findings. Furthermore, the research was conducted at a historical moment when GenAI models are rapidly evolving, meaning that the perceptions and practices documented here may change soon.

Finally, future research should explore longitudinally how these usage schemes evolve, compare GenAI appropriation across disciplines, and analyze its impact on concrete classroom practices and on students' experiences. Such studies will advance a deeper understanding of the possibilities and limits of GenAI in higher education, as well as the conditions required for its ethical, critical, and pedagogically meaningful integration.

Conclusions

The findings show that the appropriation of GenAI by university mathematics professors is still in an incipient stage, marked by the tension between pragmatic uses oriented towards efficiency and the need to construct critical and ethically grounded frameworks. This situation not only reflects how teachers relate to emerging technologies but also highlights the broader challenges faced by higher education in integrating disruptive innovations into discipline-specific practices.

From a theoretical and methodological perspective, the application of the TCF made it possible to identify the operational invariants that structure teaching practices around GenAI. This approach proved useful for analyzing educational phenomena linked to technology, providing a framework that reveals both stabilized schemes and those still under reorganization. In this sense, TCF consolidates its value as an analytical tool capable of mapping conceptualization processes in less-explored areas, such as the relationship between teachers and artificial intelligence tools.

On a practical level, the results point to the urgency of developing teacher training programs that foster a critical, creative, and context-sensitive appropriation of GenAI. Such programs should balance the use of the tool for organizational and productivity tasks with the need to preserve cognitive autonomy, academic integrity, and pedagogical mediation. Likewise, institutional policies on digital inclusion are needed to address inequalities in access, knowledge, and teachers' technological confidence.

These findings resonate with recent studies that also describe a fragmented and pragmatic appropriation of GenAI among faculty. Alshamy et al. (2025) and Larico-Hanco (2024) identified similar tendencies to rely on GenAI for organizational and technical tasks while showing hesitation to integrate it into the classroom.

Likewise, Ruediger et al. (2024) emphasized the persistence of ethical concerns and the limited pedagogical adoption of GenAI, consistent with the ambivalence documented here. The contribution of this study lies in extending these observations to the field of university mathematics education and in demonstrating, through the lens of the Theory of Conceptual Fields, how operational invariants emerge, stabilize, or remain in tension during the appropriation of disruptive technologies. This comparative dialogue underscores the

need for cross-disciplinary research that examines both the common patterns and the domain-specific challenges of integrating GenAI into higher education.

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Impacto del Proyecto Ambiental Escolar (PRAE) en la comunidad educativa: percepciones y prácticas en contextos amazónicos urbanos

Impact of the School Environmental Project (PRAE) on the Educational Community: Perceptions and Practices in Urban Amazonian Contexts

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Resumen

El estudio evalúa el impacto del Proyecto Ambiental Escolar (PRAE) en la comunidad educativa de una institución pública urbana del sur del Caquetá (Colombia). Desde un enfoque cualitativo descriptivo-analítico, se aplicaron entrevistas semiestructuradas a directivos, docentes, estudiantes y padres de familia, junto con el análisis documental del PRAE. Los datos fueron procesados en NVivo 14 mediante codificación temática y análisis de conglomerados jerárquicos. Las categorías de análisis incluyeron conocimientos, actitudes, comportamientos, estrategias pedagógicas, gestión institucional y participación comunitaria. Los resultados muestran avances en sensibilización ambiental y adopción de prácticas básicas de cuidado del entorno, pero también limitaciones en la transversalización curricular, el liderazgo institucional y la articulación con las familias. El análisis de clúster identificó dos núcleos discursivos —pedagógico-formativo e institucional-comunitario—, cuya débil conexión evidencia la necesidad de fortalecer la integración escuela–comunidad. Se concluye que el PRAE ha tenido un impacto positivo parcial en la comunidad educativa, y que su consolidación depende del desarrollo de estrategias sostenibles que articulen la gestión institucional con la práctica pedagógica y la participación ciudadana.

Palabras clave: educación ambiental, PRAE, comunidad educativa, sostenibilidad, gestión escolar.

Abstract

This study evaluates the impact of the School Environmental Project (PRAE) on the educational community of a public urban institution in southern Caquetá (Colombia). Using a qualitative descriptive-analytical approach, semi-structured interviews were conducted with school administrators, teachers, students, and parents, alongside documentary analysis of the PRAE. Data were processed using NVivo 14 through thematic coding and hierarchical cluster analysis. The analytical categories included knowledge, attitudes, behaviors, pedagogical strategies, institutional management, and community participation. The results show progress in environmental awareness and the adoption of basic environmental care practices, but also reveal limitations in curriculum integration, institutional leadership, and engagement with families. Cluster analysis identified two main discursive clusters—pedagogical-formative and institutional-community—whose weak connection highlights the need to strengthen school–community integration. The study concludes that the PRAE has had a partially positive impact on the educational community, and that its consolidation depends on the development of sustainable strategies that link institutional management with pedagogical practice and citizen participation.

Keywords: environmental education, PRAE, educational community, sustainability, school management.

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Introducción

La educación ambiental se ha consolidado como un eje estratégico para enfrentar los problemas relacionados con la crisis climática, la pérdida de biodiversidad y el uso insostenible de los recursos naturales. Organismos internacionales como la UNESCO (2022) han enfatizado la necesidad de integrar la sostenibilidad en los sistemas educativos, promoviendo la formación de ciudadanos capaces de adoptar prácticas responsables con el ambiente. En América Latina, la escuela se reconoce como un espacio clave para la construcción de cultura ambiental, en tanto posibilita el desarrollo de actitudes, valores y acciones colectivas frente a problemáticas locales y globales (Leff, 2004).

En Colombia, el Ministerio de Educación Nacional estableció los Proyectos Ambientales Escolares (PRAE) como estrategia pedagógica transversal para articular los procesos curriculares con la realidad socioambiental de cada territorio (MEN, 2017). Estos proyectos buscan que la comunidad educativa se involucre conscientemente en la identificación de problemas, el diseño de soluciones y la implementación de prácticas sostenibles en el contexto escolar y comunitario. Sin embargo, su efectividad depende en gran medida de la apropiación de los distintos actores que participan en la vida institucional.

En este contexto, el presente estudio tiene como propósito evaluar el impacto del Proyecto Ambiental Escolar (PRAE) en la comunidad educativa de una institución educativa pública urbana del sur del Caquetá (Colombia). El análisis se centra en las percepciones de directivos, docentes, estudiantes y padres de familia, con el fin de comprender en qué medida esta estrategia ha contribuido al fortalecimiento de conocimientos, actitudes y prácticas sostenibles dentro y fuera del aula.

Examinar la coherencia entre los lineamientos institucionales y las experiencias vividas por los distintos actores permite identificar avances, vacíos y desafíos en la implementación del PRAE como herramienta pedagógica para la sostenibilidad. De esta manera, el estudio busca aportar evidencias empíricas que orienten el fortalecimiento de la educación ambiental en contextos amazónicos urbanos, donde la escuela constituye un eje articulador entre formación, territorio y transformación social.

Revisión de literatura

Conceptualización de los proyectos ambientales escolares (PRAE)

En Colombia, los Proyectos Ambientales Escolares (PRAE) se conciben desde la década de 1990 como una estrategia pedagógica transversal para formar conciencia ambiental en la comunidad educativa. Diversos autores destacan que el PRAE, como política educativa, ha enfrentado limitaciones conceptuales: tradicionalmente se ha centrado en una visión ecológica instrumental del ambiente, desconectada de dimensiones sociales y culturales. Galindo-Quiroga et al. (2024) realizaron un análisis documental crítico del PRAE y subrayan que su enfoque tiende a reducirse a lo ecológico-conservacionista, sin integrar suficientemente las interdependencias socioambientales y las subjetividades ambientales de docentes y estudiantes. De igual forma, Corbetta (2021) propone incorporar una dimensión crítica a través de la construcción de puentes desde un pensamiento ambiental y latinoamericano; este enfoque aboga por proyectos más sistémicos, interdisciplinarios y participativos que trasciendan la dimensión físico-natural y fomenten habilidades prácticas para el cuidado del entorno.

Por lo tanto, a nivel conceptual se resalta la necesidad de resignificar el PRAE como un dispositivo educativo integral, transversal al currículo (no aislado en ciencias naturales) y articulado con la realidad sociocultural de la comunidad (Velásquez, 2009). Varios estudios coinciden en que la educación ambiental escolar debe pasar de ser un cumplimiento burocrático a convertirse en una experiencia vivencial y transformadora, en diálogo con los saberes locales y orientada a la acción colectiva (Mendoza-Alba et al., 2023).

Evaluación e impacto educativo de los PRAE

Entre 2015 y 2025 se han multiplicado las investigaciones evaluativas de PRAE en Colombia, evidenciando tanto logros como problemas pedagógicos. Muchos estudios de caso reportan impactos positivos en el conocimiento y las actitudes ambientales del alumnado. Por ejemplo, Prentt Orozco et al. (2025) documento en el municipio del Cesar, Colombia, que la implementación de estrategias lúdicas socioambientales (como huertos, cine ambiental, jornadas de limpieza) dentro del PRAE fortaleció la cultura ambiental de alumnos

de primaria, aumentando su participación activa y sentido de responsabilidad ecológica. García (2019) reporta una experiencia exitosa de fortalecimiento del PRAE en Tolima mediante metodologías activas (Aprendizaje Basado en Problemas) y semilleros estudiantiles: los resultados muestran cambios en las prácticas escolares (ej. proyectos de reforestación, mejor manejo de residuos) y mejoras en la convivencia basada en el respeto al entorno. Estas evaluaciones sugieren que cuando el PRAE se integra con pedagogías participativas, puede producir aprendizajes significativos y fomentar valores ambientales en la comunidad educativa.

No obstante, las limitaciones e inconsistencias en la ejecución de los PRAE son una constante en la literatura. Varios diagnósticos revelan baja participación de algunos actores (especialmente padres de familia y comunidad local) y una débil articulación institucional de estos proyectos. Un estudio en Montería (Agudelo Nisperuza et al., 2024) encontró que la comunidad educativa desconocía o no se involucró en el diseño y evaluación del PRAE de sus colegios. Igualmente, Quimbayo Guarín & Pacheco Sierra (2016), al examinar un PRAE en una escuela de Bogotá, concluyeron que el proyecto no había logrado impactar a la mayoría de estudiantes ni docentes, en parte por el desinterés docente, la falta de formación en problemáticas ambientales y la ausencia de sentido de pertenencia hacia el entorno.

Múltiples casos en distintas regiones (Sincelejo, Pasto, Suba, etc.) reportan problemas semejantes: escasa inclusión de PRAE en el Proyecto Educativo Institucional (PEI), falta de metodologías pedagógicas innovadoras, poca sistematización y evaluación continua, y actividades puntuales sin continuidad (Pulido Rojas et al., 2016; Portilla Ortega et al., 2021). Por ejemplo, Pulido Rojas et al. (2016) analizaron un PRAE rural en Boyacá y detectaron debilidades en su formulación, desarrollo e impacto, atribuyendo la baja efectividad a la ausencia de estrategias pedagógicas sólidas, mínimas instancias de reflexión crítica y una débil apropiación comunitaria del proyecto. De manera similar, evaluaciones recientes advierten que muchos PRAE se quedan en actividades aisladas (p. ej., celebraciones ambientales) y no logran resolver problemas ambientales locales ni generar participación sostenida más allá de la escuela (Mora-Ortiz, 2015; Pérez-Vásquez et al., 2021; Salcedo et al., 2023).

A nivel pedagógico, se resalta la falta de transversalización real: con frecuencia la educación ambiental sigue confinada al área de ciencias naturales, en lugar de permear todas las asignaturas (Rivas-Escobar et al., 2021). En suma, los hallazgos nacionales muestran un contraste entre la intención de los PRAE –formar una ciudadanía ambiental crítica– y la realidad de su implementación parcial, con logros principalmente en sensibilización, pero impactos limitados en la gestión ambiental del entorno (Mora-Ortiz, 2015; Espinosa Rojas & Castaño Barrera, 2022). Esto plantea la necesidad de fortalecer la planeación, seguimiento y evaluación de los PRAE, así como de involucrar a todos los estamentos escolares y comunitarios en su desarrollo.

Impacto educativo y social de los PRAE

A pesar de los avances, la evaluación de proyectos de educación ambiental escolar revela vacíos persistentes que deben atenderse para potenciar su impacto educativo y social particularmente en las comunidades educativas. En la dimensión pedagógica, se señala la falta de integración curricular plena de la educación ambiental. Muchos PRAE operan al margen del currículo formal o dependen del voluntarismo de unos pocos docentes líderes, lo que limita su alcance.

Estudios en Colombia (Sepúlveda Gallego, 2007; Ojeda González, 2023) ya advertían que la obligatoriedad normativa del PRAE no garantiza su ejecución de calidad: algunas instituciones diseñan el proyecto por cumplir requerimientos, pero sin transversalizar contenidos ambientales en todas las asignaturas ni sinergias con otros proyectos escolares. Para superar esto, autores como Ramírez Pita (2024) sugieren adoptar un enfoque curricular más complejo y holístico, donde el PRAE se conciba como una alternativa curricular que articule los ejes de sostenibilidad con las prácticas pedagógicas diarias. Se requieren guías metodológicas para que los docentes incorporen la perspectiva ambiental en todas las áreas del conocimiento, superando la visión de que la educación ambiental es exclusiva de ciencias naturales.

En relación con los aspectos metodológicos, se encontró que las metodologías participativas (investigación-acción, aprendizaje basado en proyectos, trabajo por problemas locales) se proponen como camino para involucrar activamente a los estudiantes en la identificación y solución de problemas ambientales de su contexto (Rivera-Gallego, 2024; Meza-Salcedo et al., 2023). Esta selección de metodologías obedece

principalmente a la promoción de un aprendizaje más significativo y el desarrollo de pensamiento crítico y ciudadano en el alumnado.

En la dimensión comunitaria, el gran desafío identificado es ampliar el radio de acción del PRAE más allá de las puertas de la escuela. Numerosas evaluaciones critican que los PRAE se quedan "hacia adentro", sin articularse con las familias, autoridades locales u organizaciones comunitarias (Bedoya Mejía et al., 2015; Mendoza-Ríos, 2023). La participación de padres y comunidad suele ser baja –por ejemplo, un estudio en Montería reportó solo un 36.8% de involucramiento comunitario en las actividades de los PRAE– y esto disminuye las posibilidades de impacto en el entorno.

En ese orden de ideas, autores como Bedoya Mejía et al. (2015) enfatizan la importancia de mejorar los procesos de comunicación y divulgación de los proyectos ambientales escolares: cuando la información y los logros del PRAE no se socializan efectivamente, se reducen el compromiso y el apoyo de la comunidad educativa más amplia. En contraste, experiencias donde se reformuló el PRAE con participación colectiva (estudiantes, docentes, directivos y padres) muestran mayor empoderamiento y sentido de apropiación. Por ejemplo, Meza-Salcedo et al. (2023) documentan cómo la reformulación participativa de un PRAE en Colombia fortaleció la ciudadanía ambiental escolar, generando propuestas críticas desde la comunidad educativa y mejorando los mecanismos de participación democrática en la escuela. Esto sugiere que convertir el PRAE en un proyecto de toda la comunidad escolar –y no solo de un grupo de profesores– es clave para su éxito a largo plazo. Asimismo, se advierte la necesidad de apoyo institucional y financiero: sin recursos adecuados y sin respaldo de las directivas y entes gubernamentales, muchos PRAE quedan en actividades aisladas o decaen con el tiempo (Portilla Ortega et al., 2021). La colaboración interinstitucional (alianzas con universidades, ONG, autoridades ambientales) también ha sido señalada como factor que puede amplificar el impacto de los proyectos, brindando asesoría técnica y continuidad (Mendoza-Alba et al., 2023).

En conclusión, la evaluación de las investigaciones relacionadas con el impacto de los PRAE en las comunidades muestra que estos proyectos tienen un alto potencial educativo, evidenciado en mejoras en conocimientos, actitudes y participación ambiental de los estudiantes. Sin embargo, revelan al mismo tiempo importantes desafíos: integrar verdaderamente la educación ambiental en la pedagogía cotidiana, fomentar una participación comunitaria amplia y sostenida, y desarrollar sistemas de evaluación más sólidos para medir su impacto real en la escuela y el territorio. Las implicaciones educativas apuntan a que la educación ambiental escolar no debe quedar como "tarea inconclusa" o simplemente discursiva (Pérez-Vásquez et al., 2021), sino traducirse en prácticas transformadoras. Lograrlo requiere repensar el PRAE como un eje articulador del proyecto educativo y comunitario, dotándolo de metodologías activas, apoyo institucional y mecanismos participativos que formen ciudadanos ambientalmente responsables y comprometidos con la solución de las problemáticas socio-ecológicas locales. Solo así estos proyectos podrán trascender el papel y convertirse en auténticas herramientas de cambio educativo y social hacia la sostenibilidad.

Metodología

El estudio se desarrolló desde un enfoque cualitativo, descriptivo e interpretativo, apropiado para comprender los significados que los actores educativos atribuyen al Proyecto Ambiental Escolar (PRAE) y a su influencia en la formación ambiental de la comunidad educativa. Este tipo de enfoque, como señala Cairo (2023) permite analizar la realidad educativa en su contexto natural, explorando percepciones, experiencias y discursos más allá de la cuantificación.

La investigación se asumió como un estudio de caso, centrado en una Institución Educativa ubicada en la zona urbana de Cartagena del Chairá (Caquetá, Colombia), donde el PRAE constituye una estrategia institucional de sensibilización y acción ambiental. La muestra fue intencional, integrada por 338 participantes: siete directivos, cuarenta y tres docentes, doscientos sesenta y cuatro estudiantes y ochenta y cuatro padres de familia. Esta diversidad permitió captar las distintas percepciones sobre el proyecto, tanto desde la planeación institucional como desde la práctica pedagógica.

Para la recolección de información se aplicaron entrevistas semiestructuradas y encuestas abiertas, diseñadas con base en seis categorías de análisis derivadas de la literatura sobre educación ambiental y gestión escolar: conocimientos ambientales, actitudes y valores, comportamientos y hábitos, estrategias pedagógicas, gestión institucional y participación comunitaria, así:

Tabla 1.
Categorías de análisis

Categoría	Descripción
Conocimientos ambientales	Conocimiento de estudiantes, docentes y padres de familia sobre medio ambiente y PRAE.
Actitudes y valores ambientales	Sentimientos, motivaciones, responsabilidad ambiental.
Comportamientos y hábitos	Acciones concretas derivadas del PRAE.
Estrategias pedagógicas del PRAE	Cómo se enseña y articula el PRAE en el aula.
Gestión institucional y liderazgo	Rol de directivos, continuidad, apoyo y recursos.
Participación de la comunidad y padres	Implicación de familias y actores externos.

De manera complementaria, se realizó un análisis documental del Proyecto Ambiental Escolar institucional (versión 2024), contrastando los objetivos, ejes temáticos y estrategias pedagógicas declaradas con las percepciones empíricas de los actores.

Como afirman Armando (2023), el análisis de los PRAE debe contemplar no solo su existencia normativa, sino también su capacidad de transformar la cultura ambiental escolar. Esta revisión documental permitió triangular la información y valorar la coherencia entre la planificación institucional y la práctica educativa, siguiendo la perspectiva latinoamericana que concibe la educación ambiental como un proceso cultural y socialmente situado.

El procesamiento de los datos se realizó con el software NVivo 14, que facilitó la codificación mixta (deductiva e inductiva) y la generación de nubes de palabras y un dendrograma jerárquico de similitud. Estas herramientas permitieron visualizar las relaciones semánticas entre las categorías y los grupos de actores, y evidenciar los núcleos discursivos pedagógico-formativo y comunitario-institucional, siguiendo las recomendaciones de Jackson & Bazeley (2019) para el uso de software de análisis cualitativo.

Finalmente, la investigación se desarrolló conforme a los principios de la Ley 1581 de 2012, garantizando la protección de datos personales, el consentimiento informado y el uso exclusivamente académico de la información recolectada.

Resultados y discusión

El presente apartado expone los resultados obtenidos en la investigación sobre el impacto del Proyecto Ambiental Escolar (PRAE) en la formación ambiental de la comunidad educativa de una Institución pública en Cartagena del Chairá. Los hallazgos surgen de la interpretación integrada de tres fuentes de información: entrevistas, encuestas abiertas y el documento institucional del PRAE, cuyos contenidos fueron triangulados para comprender tanto las percepciones de los actores como la coherencia entre la planeación y la práctica pedagógica.

Conocimientos ambientales

En el marco del PRAE, los docentes han abordado una variedad de contenidos ambientales que reflejan tanto las prioridades institucionales como las preocupaciones del contexto territorial. Estos temas, aunque diversos en su enfoque, permiten identificar qué dimensiones del saber ambiental han sido enfatizadas en la práctica pedagógica. La selección y frecuencia de los contenidos no solo evidencia el tipo de conocimientos promovidos en el aula, sino también las formas en que los docentes interpretan su rol frente a la educación ambiental. A continuación, se sintetizan las principales temáticas identificadas a partir del análisis de las respuestas docentes.

El gráfico presenta una síntesis temática de los conocimientos ambientales abordados en el marco del PRAE desde la perspectiva docente. Los temas se organizan en torno a contenidos tanto ecológicos como contextuales y éticos, lo que evidencia una visión amplia de la educación ambiental. Se destacan nociones clásicas como el reciclaje y la reutilización, el cuidado del agua y la contaminación, pero también se incluyen enfoques más complejos como el cambio climático, el desarrollo sostenible y la conservación de los ecosistemas. Ver figura 1.

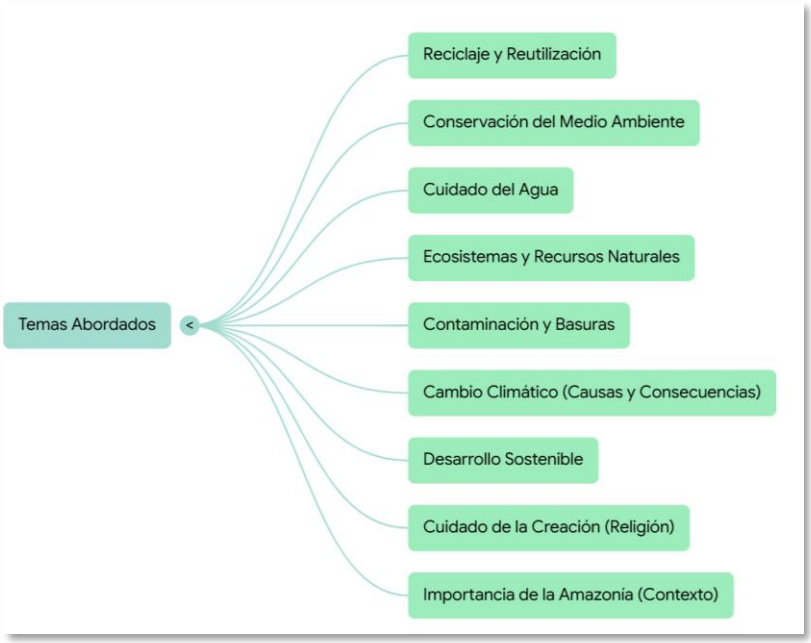

Figura 1. Síntesis temática de los conocimientos ambientales abordados en el marco del PRAE desde la perspectiva docente.

La inclusión de temas como el cuidado de la creación (Religión) y la importancia de la Amazonía muestra una apropiación situada del PRAE, donde se integran dimensiones culturales, territoriales y espirituales al proceso formativo. Esta diversidad temática revela que los docentes no solo transmiten información ambiental, sino que promueven reflexiones sobre el vínculo entre ser humano, entorno y territorio, articulando saberes científicos y locales. En conjunto, el mapa temático evidencia un abordaje integral de la educación ambiental en el aula, con potencial para fortalecer la conciencia crítica y el compromiso con el contexto amazónico.

Por otra parte, se realizó el análisis discursivo de los diferentes actores frente a los conocimientos ambientales. Para el caso de estudiantes, el análisis léxico de las respuestas representadas en la nube de palabras (figura 1), refuerza esta interpretación. Los términos de mayor frecuencia —*"basura", "contaminación", "comunidad", "residuos", "desperdicio" y "suelos"*— reflejan una comprensión centrada en los problemas visibles de la contaminación y el manejo de desechos, más que en las relaciones ecológicas o los procesos sistémicos del ambiente.

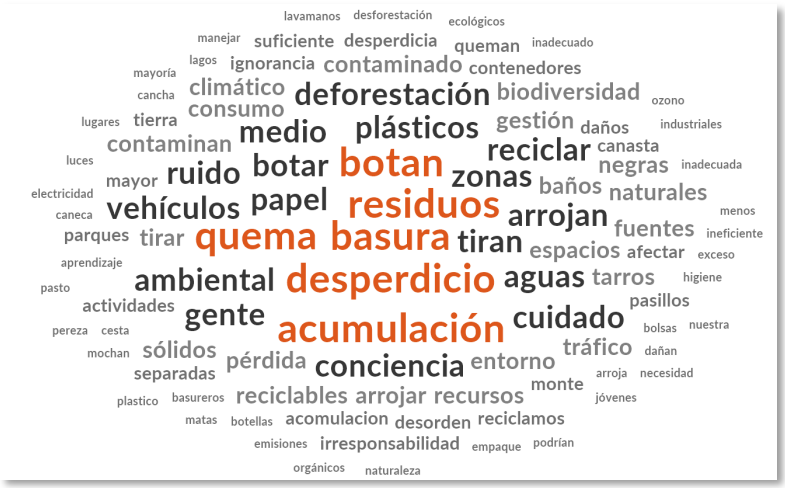

Figura 2. Nube de palabras sobre percepciones de los estudiantes en torno al conocimiento ambiental (NVivo 14).

La alta recurrencia de palabras asociadas al acto de desechar (*botar*, *arrojar*, *tirar*) muestra que los estudiantes vinculan el conocimiento ambiental con hábitos de limpieza y cuidado físico del entorno, lo que coincide con el enfoque operativo identificado en las entrevistas. Esta tendencia confirma que el saber ambiental escolar se construye más desde la acción práctica que desde la reflexión conceptual, lo que coincide con lo planteado por Henao Hueso & Sánchez Arce (2019) sobre el predominio de aprendizajes empíricos en los PRAE latinoamericanos.

Por otra parte, la nube de palabras elaborada a partir de los discursos docentes (Figura 2) refleja que los conceptos más recurrentes son "residuos", "agua", "cuidado", "ahorro" y "clasificación". Este patrón evidencia que el conocimiento ambiental se orienta principalmente hacia dimensiones operativas y de gestión de recursos, centradas en la preservación del agua y el manejo de residuos sólidos.

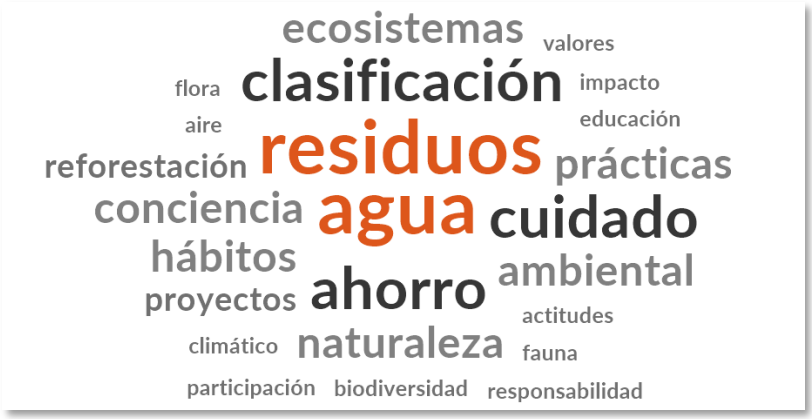

Figura 3. Nube de palabras sobre percepciones de los docentes en torno al conocimiento ambiental (NVivo 14).

Si bien los términos asociados —como *"conciencia"*, *"hábitos"* y *"responsabilidad"*— denotan una preocupación ética por el entorno, su menor frecuencia sugiere que las nociones de ecosistema, biodiversidad o cambio climático aún tienen una presencia marginal en la comprensión docente.

En términos pedagógicos, esta tendencia indica que el conocimiento ambiental promovido por el PRAE se mantiene en un nivel pragmático y conductual, más orientado a la acción inmediata que a la reflexión crítica sobre las causas y consecuencias socioambientales. Este hallazgo coincide con lo planteado por Galindo-Quiroga (2024) quien afirma que los PRAE no solo deben enfocarse en la transmisión de conocimientos sobre el medio ambiente, sino también en el desarrollo de competencias y habilidades para la acción responsable y la ciudadanía ambiental activa.

De forma complementaria, la nube de palabras de los padres de familia (Figura 3) evidencia una representación del conocimiento ambiental más cotidiana y experiencial, centrada en términos como "basura", "agua", "naturaleza" y "conciencia".

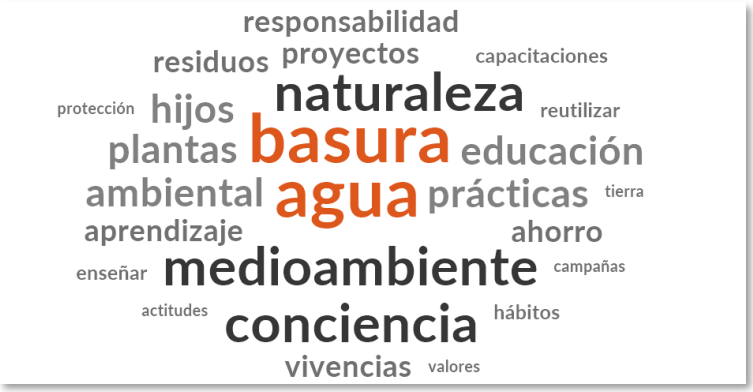

Figura 4. Nube de palabras sobre percepciones de los docentes en torno al conocimiento ambiental (NVivo 14).

A diferencia del discurso docente, donde predomina una visión técnica orientada a la gestión de recursos, las familias vinculan la educación ambiental con el aprendizaje moral y la transmisión de valores a sus hijos. El énfasis en expresiones como "enseñar", "aprendizaje" y "responsabilidad" sugiere que los padres conciben el cuidado ambiental como una tarea compartida entre escuela y hogar, aunque su comprensión del PRAE se limita a acciones visibles como campañas, ahorro de agua o manejo de residuos.

Esta tendencia coincide con lo expuesto por Meza-Salcedo et al. (2023), quienes sostienen que la educación ambiental comunitaria se sostiene más en las vivencias y actitudes familiares que en procesos sistemáticos de formación. En este sentido, los saberes ambientales parentales son relevantes, pero todavía se encuentran poco articulados con las estrategias pedagógicas institucionales, lo que limita su potencial transformador en la comunidad.

En síntesis, los resultados ilustran visualmente el tipo de conocimiento ambiental predominante: uno conductual y descriptivo, orientado a la gestión de residuos y a la preservación del espacio inmediato, pero con baja integración de perspectivas científicas o ecosistémicas más amplias.

Por otra parte, los resultados revelan que el conocimiento sobre el PRAE institucional es limitado y fragmentado. Una parte considerable de los estudiantes manifestó no conocer con claridad los objetivos o líneas de acción del proyecto, y lo asocian principalmente con actividades puntuales —como jornadas de limpieza o siembra de árboles— más que con un proceso educativo continuo.

Por su parte, los docentes, aunque reconocen que el PRAE promueve aprendizajes significativos, la mayoría lo concibe como una "actividad complementaria" más que como un eje transversal del currículo. Este hallazgo coincide con el documento PRAE institucional, cuyo objetivo general plantea *"fomentar en la comunidad educativa una cultura ambiental sostenible en el contexto amazónico mediante estrategias pedagógicas y didácticas transversales"*. El contraste entre lo declarado en el documento y las percepciones empíricas sugiere que la intencionalidad formativa no se ha traducido en un conocimiento institucional sólido ni en apropiación conceptual del proyecto.

Desde el punto de vista teórico, estos resultados se relacionan con lo planteado por Rodríguez & Flores (2022), quienes destacan que la educación ambiental en América Latina ha privilegiado la sensibilización sobre el conocimiento estructurado, lo cual genera vacíos cognitivos en la comprensión sistémica del ambiente. De forma similar, Henao Hueso & Sánchez Arce (2019) advierten que la falta de integración curricular impide que los estudiantes comprendan el ambiente como una red de interacciones ecológicas, sociales y culturales.

En consecuencia, la formación ambiental escolar continúa centrada en acciones prácticas más que en el desarrollo de pensamiento crítico y comprensión integral del ambiente. Esto plantea la necesidad de fortalecer el componente cognitivo del PRAE mediante estrategias pedagógicas que integren el saber científico, los saberes locales y la reflexión interdisciplinar.

Actitudes y valores ambientales

Los resultados obtenidos muestran que las actitudes y valores ambientales se han convertido en uno de los logros más visibles del PRAE en la institución. Tanto docentes como estudiantes y padres de familia expresaron sentimientos de compromiso, respeto y cuidado hacia el entorno, aunque estos valores se manifiestan principalmente en el plano emocional y simbólico más que en acciones sostenidas.

Las entrevistas revelaron frases recurrentes como "debemos cuidar el planeta", "la basura contamina" o "hay que sembrar árboles", que reflejan una conciencia ambiental declarativa, es decir, una comprensión ética y afectiva, pero con escasa reflexión crítica sobre las causas estructurales de los problemas ambientales.

Entre los docentes, las actitudes positivas se asocian al orgullo institucional y a la percepción de que el PRAE ha sensibilizado a los estudiantes; sin embargo, también reconocen baja continuidad en las campañas y ausencia de incentivos institucionales. En los estudiantes, predomina una motivación espontánea vinculada a la práctica: cuidar las plantas, mantener limpio el aula o participar en jornadas ambientales.

Estas expresiones de responsabilidad individual coinciden con lo que el PRAE institucional plantea en su objetivo específico de *"promover el sentido de pertenencia hacia el ambiente y la identidad amazónica mediante acciones de reforestación y recuperación de espacios escolares"* (Institución Educativa El Chairá José María Córdoba, 2024). No obstante, el contraste entre el documento y las percepciones evidencia que el valor ambiental se mantiene a nivel actitudinal, sin consolidarse como competencia ciudadana permanente.

Desde el marco teórico, Gallo Hoyos (2021) sostiene que la educación ambiental latinoamericana continúa orientándose a la sensibilización emocional, sin lograr que los valores ecológicos se transformen en prácticas sociales duraderas. Desde este estudio, se considera que es importante que la formación ambiental transcienda la "moral del reciclaje" e incorporar procesos de análisis crítico sobre las relaciones entre sociedad, economía y naturaleza. Los hallazgos de esta investigación evidencian que, en la institución, los valores ambientales se expresan con entusiasmo y empatía, pero aún requieren una pedagogía más reflexiva y transversal que vincule la ética ambiental con los contenidos curriculares y la acción comunitaria.

En síntesis, las actitudes ambientales en la comunidad educativa representan un avance significativo en sensibilización, pero todavía carecen de una base cognitiva y participativa que garantice su permanencia. El reto pedagógico consiste en fortalecer la educación ambiental desde la interiorización de valores, articulándolos con la acción colectiva y la comprensión crítica del territorio.

Comportamientos y hábitos ambientales

Los resultados obtenidos muestran que el PRAE ha generado ciertos cambios en los comportamientos cotidianos de la comunidad educativa, especialmente entre los estudiantes, quienes manifiestan hábitos asociados al reciclaje, la limpieza de espacios escolares, el cuidado del agua y la reforestación de zonas verdes. Ver figura 5.

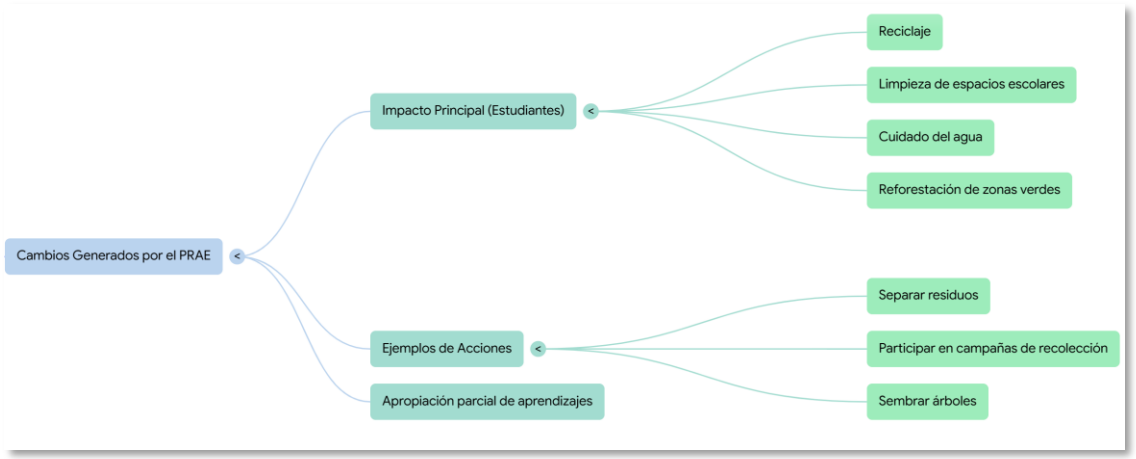

Figura 5. Cambios percibidos generados por el PRAE.

En las encuestas, los estudiantes mencionaron actividades como separar residuos, participar en campañas de recolección o sembrar árboles en los alrededores de la institución. Estas acciones demuestran una apropiación parcial de los aprendizajes ambientales y un reconocimiento del papel personal en el cuidado del entorno.

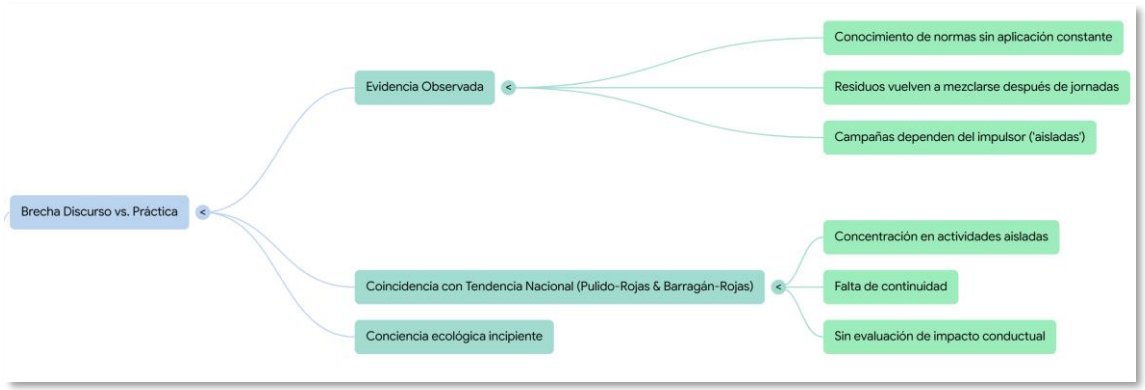

Figura 6. Brecha entre discurso y práctica.

Sin embargo, el análisis de las entrevistas y observaciones evidencia una brecha entre el discurso y la práctica. Muchos participantes afirman conocer las normas de reciclaje o la importancia del ahorro de agua, pero no las aplican de manera constante. Por ejemplo, varios docentes señalaron que, tras las jornadas ambientales, los residuos suelen volver a mezclarse y que las campañas de limpieza "dependen de quién las impulse".

Este patrón coincide con la tendencia nacional descrita por Pulido et al., (2016), quienes encontraron que los PRAE en instituciones rurales de Boyacá tienden a concentrarse en actividades aisladas, sin continuidad ni evaluación de impacto conductual.

En el mismo sentido, las percepciones de los padres de familia aportan una mirada complementaria sobre los comportamientos ambientales de los estudiantes. La mayoría coincide en que sus hijos han adquirido mejores hábitos cotidianos, especialmente en el manejo de residuos y el ahorro de agua. Comentarios como *"ya no botan basura en la calle"*, *"guardan los empaques para tirarlos en casa"* o *"cuidan las plantas del patio"* reflejan pequeños cambios positivos en el hogar, asociados a los aprendizajes escolares.

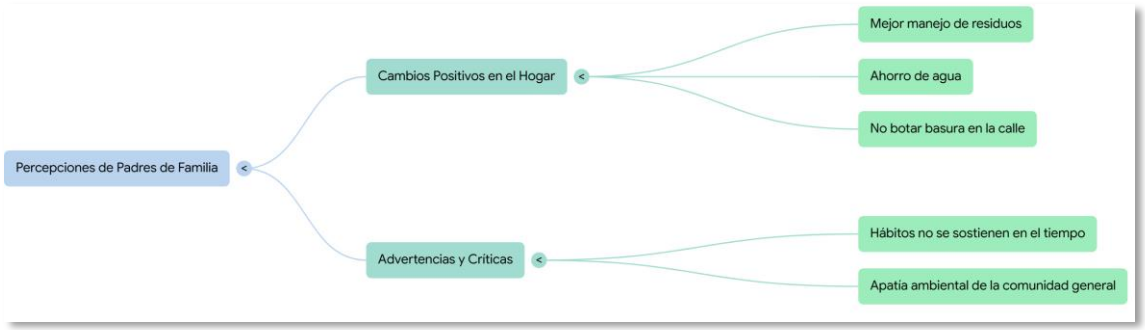

Figura 7. Percepciones de padres de familia.

No obstante, los padres también advierten que estos hábitos no siempre se sostienen en el tiempo y que la comunidad en general muestra apatía ambiental. Estas percepciones refuerzan la brecha entre conocimiento, discurso y acción sostenida, evidenciada también en los testimonios docentes. En este sentido, los padres reconocen el esfuerzo institucional del PRAE, pero sugieren una mayor articulación entre escuela, familia y territorio para consolidar una cultura ambiental compartida, como lo proponen Bedoya Mejía (2015) en su estudio sobre participación comunitaria y educación ambiental en Colombia.

El contraste con el documento institucional del PRAE confirma esta situación. Allí se proyectan acciones sostenidas de *"manejo de residuos sólidos, reforestación y preservación de la identidad amazónica"*, acompañadas de una planeación anual (Institución Educativa El Chairá José María Córdoba, 2024). No obstante, la evidencia empírica indica que la ejecución se ha reducido a campañas esporádicas y a la participación voluntaria de unos pocos grupos. Ello sugiere que el PRAE funciona más como un mecanismo de sensibilización que como un proceso formativo de transformación de hábitos ambientales.

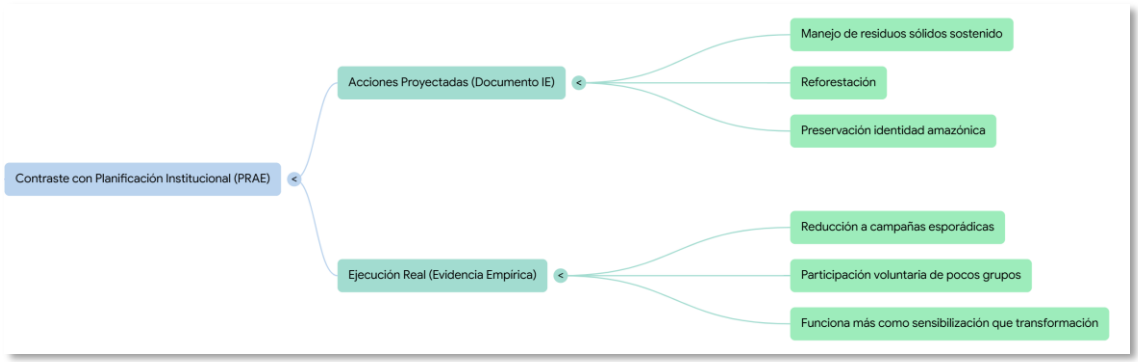

Figura 8. Contrastes de acciones proyectadas en PRAE y ejecución real.

Desde una perspectiva teórica, Boeve-de Pauw & Van Petegem (2013) demostraron, a partir de un estudio con más de dos mil estudiantes europeos, que la educación ambiental logra cambios sostenibles en el comportamiento solo cuando se vincula a experiencias prácticas, reflexivas y continuas dentro del currículo. De forma similar, Pérez & Enríquez (2021), en un estudio realizado en Cali, evidenciaron que los hábitos ambientales en los jóvenes se fortalecen cuando las actividades educativas incluyen procesos de reflexión crítica y trabajo cooperativo, no únicamente acciones instrumentales.

En la institución analizada, los comportamientos ambientales observados revelan una conciencia ecológica incipiente, traducida en acciones visibles, pero poco interiorizadas. El desafío principal radica en convertir estas prácticas en hábitos sostenibles, articulando las actividades del PRAE con el proyecto pedagógico institucional y estableciendo mecanismos de seguimiento que promuevan la continuidad y la responsabilidad compartida.

Estrategias pedagógicas del PRAE

El análisis de las entrevistas y del documento institucional evidencia que el PRAE se desarrolla principalmente a través de estrategias pedagógicas tradicionales, complementadas con algunas experiencias prácticas. En la indagación, los docentes que manifestaron haber incorporado temas ambientales en sus asignaturas, mencionaron de manera recurrente: huerta escolar, los proyectos de aula sobre reciclaje y las campañas ambientales enfocadas en el manejo de residuos, siembra de árboles o la limpieza de espacios comunes. (Ver figura 4).

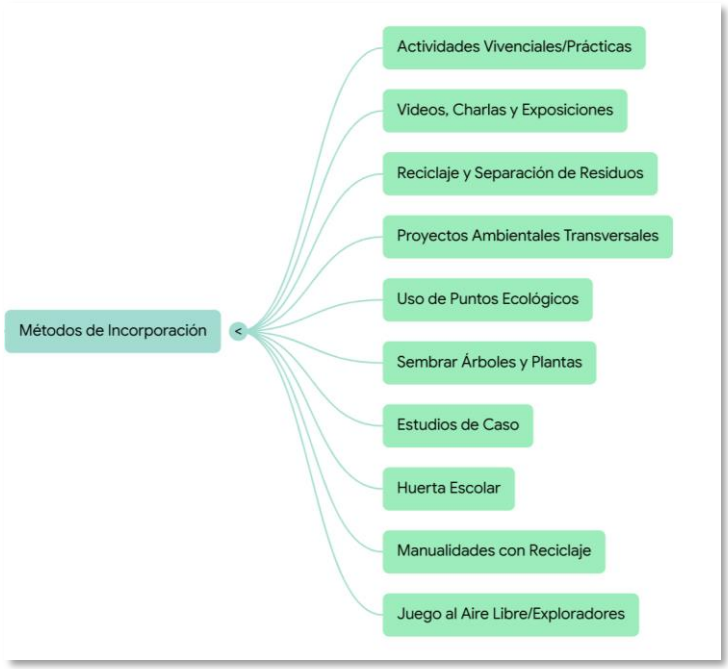

Figura 9. Métodos de incorporación del componente ambiental parte de los docentes.

Estas actividades, aunque valoradas positivamente por la comunidad educativa, se ejecutan de forma intermitente y dependiente de la motivación individual de los docentes, sin una planeación articulada al currículo institucional.

El documento del PRAE institucional declara una metodología basada en el *aprendizaje por proyectos* y en la *investigación escolar aplicada a problemas locales*, con el propósito de integrar los saberes ambientales en las diferentes áreas del conocimiento.

En la institución analizada, la ausencia de un enfoque metodológico sostenido limita la consolidación del PRAE como práctica transformadora. Se requiere, por tanto, avanzar hacia una pedagogía ambiental más activa y experiencial, que permita conectar los contenidos escolares con las realidades del contexto amazónico y fortalecer las competencias ciudadanas y científicas de los estudiantes.

Gestión institucional y liderazgo

El análisis de las entrevistas con directivos y docentes líderes del proyecto revela una visión fragmentada y operativa del PRAE, donde el liderazgo ambiental institucional se reduce a cumplir con una exigencia normativa, más que a promover una transformación educativa.
Aunque los directivos expresan reconocimiento por la importancia del proyecto, en la práctica su gestión se orienta a mantener el cumplimiento administrativo de planes y evidencias, sin una estrategia pedagógica de largo plazo. Esta postura instrumental reproduce una lógica burocrática que desvirtúa la esencia formativa del PRAE y debilita su capacidad de incidencia comunitaria.

La información obtenida evidencia vacíos estructurales en la planeación, seguimiento y asignación de recursos. Los docentes manifiestan que el proyecto carece de presupuesto propio, que la mayoría de actividades dependen de la iniciativa voluntaria de algunos maestros y que las acciones se concentran en fechas conmemorativas.
Estos testimonios contrastan con lo establecido en el documento institucional del PRAE, que plantea como meta fortalecer *"la cultura ambiental de toda la comunidad educativa a través de estrategias articuladas, con responsables definidos y cronograma de ejecución anual"*.

En la práctica, no se hallaron mecanismos de seguimiento sistemático ni indicadores verificables de logro. El liderazgo, por tanto, opera desde el compromiso personal más que desde la estructura institucional, lo que limita la sostenibilidad del proyecto.

La anterior situación refleja una ausencia de gobernanza ambiental escolar, donde la dirección institucional no asume la educación ambiental como un eje estratégico del proyecto educativo, sino como un requerimiento externo. Como advierte Bedoya Mejía et al. (2015), muchos PRAE fracasan porque no logran integrarse a los procesos de gestión escolar y permanecen subordinados a la voluntad de pocos docentes motivados.

De igual forma, Portilla et al. (2021) señalan que el liderazgo ambiental efectivo exige pasar de la coordinación simbólica a la creación de estructuras participativas que fortalezcan la corresponsabilidad y la evaluación continua. En la institución estudiada, la falta de una ruta clara de liderazgo, la inexistencia de un comité ambiental funcional y la rotación constante del personal docente han impedido consolidar un proyecto de gestión ambiental sostenido en el tiempo.

Más allá de las limitaciones operativas, el problema de fondo es pedagógico y cultural: el liderazgo institucional sigue respondiendo a una lógica vertical, donde las decisiones se centralizan y la innovación depende de permisos o avales jerárquicos. Esta estructura inhibe la autonomía de los docentes y desincentiva la participación estudiantil en la toma de decisiones ambientales. Se requiere un liderazgo ambiental que no solo administre, sino que inspire, dialogue y conecte la gestión con la práctica pedagógica, en coherencia con los principios de la educación para la sostenibilidad.

En síntesis, la gestión institucional del PRAE muestra avances en sensibilización, pero carece de la coherencia organizativa y la visión transformadora necesarias para convertirse en una política educativa viva. Mientras la educación ambiental siga siendo tratada como un proyecto accesorio, su impacto permanecerá marginal y dependiente del esfuerzo individual más que del compromiso colectivo.

Transversalización curricular y participación comunitaria

Los resultados muestran que, desde la perspectiva de los directivos, el Proyecto Ambiental Escolar (PRAE) se ha concebido como una estrategia transversal que abarca todos los niveles educativos "desde preescolar hasta grado once", con articulación entre áreas y asignación de responsabilidades específicas. No obstante, el contraste entre el plan y la práctica demuestra que esta intencionalidad pedagógica no se ha consolidado, ya que las áreas o contextos se abordan desde pocas asignaturas.

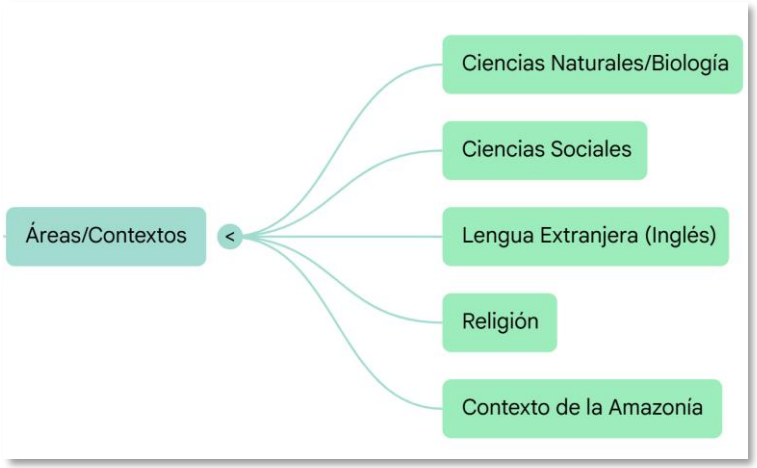

Figura 10. Áreas académicas y contextos en los que los docentes integran contenidos del PRAE

Esta situación confirma la limitada transversalización curricular, una de las debilidades históricas de los proyectos ambientales escolares en Colombia. A pesar de los avances en sensibilización, el PRAE continúa operando como un eje paralelo, más que como un componente estructurante del currículo y la cultura pedagógica institucional.

Desde la perspectiva teórica, los resultados coinciden con lo expuesto por Falconí (2019) quien señala que el docente, además del conocimiento de su asignatura, debe ser un buen ciudadano y educar en medio ambiente. Por lo tanto, la falta de formación docente en metodologías activas y al escaso acompañamiento institucional interfiere en la educación ambiental integral.

En cuanto a la participación comunitaria, los directivos destacan espacios como las *escuelas de padres*, las *campañas institucionales* y las *jornadas de siembra o limpieza* ("sembratones") como formas de vinculación externa. Sin embargo, desde la voz de los estudiantes, emerge la propuesta de crear brigadas ecológicas y liderazgos estudiantiles, así como de establecer puntos ecológicos permanentes y normas claras de uso de espacios escolares.
Por su parte, varias familias manifiestan su interés en participar de manera más activa, pero demandan mejor comunicación y formación ambiental básica que les permita apoyar el proceso desde el hogar.

Balance interpretativo del impacto

En conjunto, estos hallazgos revelan una intención institucional genuina de transversalizar y convocar, aunque en la práctica las experiencias vividas por los distintos actores muestran heterogeneidad, discontinuidad y escasa articulación entre escuela y comunidad.
El análisis de conglomerados jerárquicos refuerza esta interpretación, al evidenciar dos núcleos discursivos diferenciados.

Figura 11. Dendrograma jerárquico de similitud de palabras entre actores y categorías del PRAE (NVivo 14)

El primero, de carácter institucional-comunitario, agrupa a *directivos y padres* en torno a las categorías *C6. Participación comunitaria* y *C3. Comportamientos y hábitos*, configurando una visión pragmática y operativa del PRAE, enfocada en la gestión y las campañas. El segundo conglomerado, de naturaleza pedagógica-formativa, reúne a *docentes y estudiantes* alrededor de las categorías *C1. Conocimientos ambientales*, *C2. Actitudes*, *C4. Estrategias pedagógicas* y *C5. Gestión institucional y liderazgo*, enfatizando los procesos de enseñanza, sensibilización y aprendizaje ambiental.

La distancia entre ambos núcleos evidencia una débil articulación entre la gestión institucional y la práctica pedagógica, una situación que coincide con los hallazgos de Bedoya Mejía et al. (2015) y Rivas-Escobar et al. (2021), quienes advierten que la mayoría de los PRAE en Colombia enfrentan dificultades para integrar la dimensión comunitaria con los procesos formativos escolares.

Esta brecha sugiere que el fortalecimiento de la transversalización curricular requiere no solo planificación, sino también estructuras de liderazgo compartido y espacios permanentes de coformación escuela–familia–territorio.

Ahora bien, como se muestra en la *Tabla 2*, los agrupamientos discursivos identificados confirman esta dualidad entre los enfoques comunitario y pedagógico, destacando además puntos de desconexión que requieren estrategias de integración sostenida entre la escuela y su entorno.

Tabla 2.
Agrupamientos discursivos identificados en el análisis jerárquico

Agrupamiento	Actores principales	Categorías asociadas	Interpretación
Enfoque comunitario	Directivos y padres	C6. Participación / C3. Comportamientos	Visión pragmática del PRAE, centrada en campañas, jornadas y liderazgo institucional.
Enfoque pedagógico-formativo	Docentes y estudiantes	C1. Conocimientos / C2. Actitudes / C4. Estrategias / C5. Gestión	Se orienta al aprendizaje ambiental, priorizando sensibilización y conocimiento más que acción sostenida.
Puntos de desconexión	Entre los dos bloques	—	Evidencia débil articulación entre la gestión institucional y la práctica pedagógica. Requiere estrategias de integración escuela–comunidad.

En síntesis, aunque el PRAE consolida un marco institucional que promueve la transversalización y la participación, la práctica evidencia dos sistemas paralelos: uno administrativo y comunitario, y otro pedagógico y formativo, con escasa convergencia.
La consolidación de una educación ambiental transformadora exige superar esta fragmentación mediante liderazgos compartidos, continuidad institucional y espacios reales de participación escuela–comunidad.

Conclusiones

El estudio permitió valorar el impacto del Proyecto Ambiental Escolar (PRAE) en la comunidad educativa de una institución pública urbana del municipio de Cartagena del Chairá, Caquetá, evidenciando que este proyecto ha contribuido al desarrollo de procesos de sensibilización, aprendizaje y acción ambiental entre docentes, estudiantes, directivos y familias.

Los resultados muestran que el PRAE ha fortalecido el conocimiento sobre el cuidado del agua, la clasificación de residuos y la conservación del entorno, consolidando una base de conciencia ambiental colectiva. No obstante, el análisis integral de las categorías revela que el impacto del proyecto sigue siendo parcial y heterogéneo, pues la transversalización curricular y la continuidad de las acciones aún dependen del liderazgo y compromiso de algunos actores.

El trabajo colaborativo entre docentes y estudiantes se destaca como una de las fortalezas más visibles, mientras que la vinculación de las familias y la comunidad requiere mayores espacios de participación y formación ambiental.

El análisis de conglomerados jerárquicos permitió identificar dos tendencias discursivas: una pedagógico-formativa, centrada en la enseñanza y el aprendizaje ambiental, y otra institucional-comunitaria, orientada a la gestión y la acción práctica. La distancia entre ambas refleja la necesidad de articular los procesos pedagógicos con las estrategias institucionales, de modo que el PRAE opere como un sistema integrado de educación ambiental y no como una suma de actividades.

En conjunto, los hallazgos confirman que el PRAE 2024 representa un avance conceptual y organizativo, pero requiere fortalecer el seguimiento, la evaluación y la continuidad pedagógica para consolidar una cultura ambiental escolar.

En contextos amazónicos urbanos, esta experiencia demuestra que la escuela tiene el potencial de convertirse en eje articulador entre la formación, la participación y la sostenibilidad, promoviendo aprendizajes significativos y prácticas transformadoras hacia un desarrollo ambiental responsable. Además, contribuye no solo al aprendizaje ambiental, sino también al tejido social y a la sostenibilidad del territorio.

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The role of geographical and legal features in optimizing security and control of semi-enclosed seas: A case study of the eastern Adriatic Sea

Uloga geografskih i pravnih obilježja poluzatvorenih mora u optimizaciji sigurnosti i nadzora: studija slučaja istočnog Jadranskog mora

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Abstract

Semi-enclosed seas are geographic areas specifically defined by their general geometry. Geographical characteristics heavily influence the possibilities and challenges of surveillance, security and navigation of semi-enclosed seas. This paper analyses specifications and typical challenges that occur within the semi-enclosed seas, firstly by defining them and secondly by comparing different challenges that occur within different geographical areas. The causality of typical challenges is then correlated to geomorphological, geopolitical and

Sažetak

Poluzatvorena mora su geografska područja posebno definirana svojom općom geometrijom. Geografske značajke snažno utječu na mogućnosti i izazove nadzora, sigurnosti i navigacije u poluzatvorenim morima. Ovaj rad analizira specifičnosti i tipične izazove koji se javljaju u poluzatvorenim morima, prvenstveno njihovom definicijom, a zatim usporedbom različitih izazova koji nastaju u različitim poluzatvorenim morima. Uzroci tipičnih izazova potom se povezuju s geomorfološkim, geopolitičkim i hidrometeorološkim svojstvima poluzatvorenih

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hydrometeorological properties of semi-enclosed seas. Heavy focus is on the problematics arising on the eastern coast of Adriatic. These are further compared to the general properties of challenges occurring in the semi-enclosed seas analysed by comparison of different regions, resulting in not only a correlation between semi-enclosed sea properties, but also a clear systematizations and categorization of those problems which will enable further research on combating them.

Keywords: Semi-enclosed sea, security, surveillance, Adriatic.

mora. Poseban naglasak stavljen je na problematiku koja nastaje na istočnoj obali Jadrana. Ona se dalje uspoređuje s općim obilježjima izazova prisutnih u poluzatvorenim morima analiziranim usporednim prikazom različitih regija, što rezultira ne samo utvrđivanjem povezanosti između svojstava poluzatvorenih mora i samih problema, već i jasnom sistematizacijom i kategorizacijom tih problema koja će omogućiti daljnja istraživanja u svrhu prevladavanja istih.

Ključne riječi: Poluzatvoreno more, sigurnost, nadzor, Jadran.

Introduction

The precondition for achieving a higher level of maritime security for coastal states with access to semi-enclosed seas is the effective implementation of sea control and protection to reduce threats and risks at sea. The analysis of the maritime situation is defined as a process, an examination of the situation, its elements and their relationships. Early detection and neutralization of threats posed by vessels is one of the key tasks of coastal state services in the context of control and protection of maritime traffic, as well as critical infrastructure.

For the purpose of maritime security, control and protection systems are organized depending on: the sea surface area, geostrategic position, and meteorological-oceanographic conditions of the coast and islands. Given the demanding task of maritime traffic surveillance and control of the state border at sea, the spatial features of semi-enclosed seas have been defined and analysed with the goal of improving the effectiveness of existing management models and future deployment of resources by state administration bodies.

First section of this paper provides a detailed analysis of the features and properties of semi-enclosed seas, with focus on Adriatic. Furthermore, analytical comparison of different challenges of various semi-enclosed seas worldwide helps to correlate specific challenges to specific properties and provide a systematic overview linking typical causes to typical problems.

Second section analyses how the nature of semi-enclosed seas influences navigation and surveillance on the Adriatic. Moreover, an analysis of the common problems of eastern Adriatic is compared and categorized within the systematic framework that was presented in the first section, further strengthening the systematic framework as well as providing additional information and findings that might in future help to find easier ways to combat said challenges. All abbreviations used in the preparation of this paper are listed in the nomenclature table.

Table 1.
Nomenclature

RC Republic of Croatia	NtM Notices to Mariners
SAB State Administration Bodies	VHF Very High Frequency
RI Republic of Italy	MF Medium Frequency
RG Republic of Greece	DSC Digital Selective Calling
IW Internal Waters	NAVTEX NAVigational TElex
TS Territorial Sea	INMARSAT International Maritime Satellite Organization
EEZ Exclusive Economic Zone	CRS Coastal Radio Stations
CS Continental Shelf	IMO International Maritime Organization
UNCLOS United Nations Convention on the Law of the Sea	

Methodology

This paper adopts a qualitative and comparative case-study approach to examine the challenges of maritime surveillance along the eastern Adriatic coast. The methodological choice stems from the recognition that surveillance difficulties on eastern Adriatic arise not from a single variable but from the interplay of

geomorphology, hydrometeorology, legal frameworks, and institutional structures. Rather than seeking quantifiable performance measures of technical systems, the study employs interpretive analysis to identify recurring patterns and categories of constraints.

The primary unit of analysis is the eastern Adriatic, understood as a part of a semi-enclosed sea system under the definition of the UNCLOS. Within this framework, the paper investigates both the legal-institutional context (border disputes, maritime spatial planning, institutional fragmentation) and the technical-environmental context (impacts of geomorphology and hydrometeorology on surveillance).

A comparative method is applied by situating Croatia's challenges within the broader category of semi-enclosed and indented seas. Comparative references include the Baltic, the Aegean, and selected chokepoints such as the Strait of Hormuz and Bab el-Mandeb. These examples are not used to provide exhaustive regional surveys, but to highlight the structural similarities that arise when semi-enclosed geography and fragmented governance intersect.

Finally, the limitations of the methodology must be acknowledged. The analysis is based on open-source academic and legal material; classified technical or operational naval data are not included. The findings therefore remain conceptual and structural in nature, oriented toward understanding patterns rather than evaluating the performance of specific systems.

Literature review

The materials for this study consist of legal documents, academic literature, and applied case studies.

At the international level, UNCLOS provides the legal definition of semi-enclosed seas, as well as principles relevant to cooperation and surveillance. European Union frameworks on maritime spatial planning further inform the legal-institutional context, establishing requirements for coherence and integration across member states.

At the national level, Croatian legislation and policy documents relating to maritime spatial planning, concessions, and jurisdiction form a crucial material basis. Scholarly work has emphasized the persistence of institutional fragmentation and the underdevelopment of GIS infrastructure in eastern Adriatic maritime governance. While regional GIS applications exist, the absence of a comprehensive national framework reduces integration and limits cross-sectoral coordination.

The geomorphological features of the Adriatic are a further focus of the literature. The eastern Adriatic is characterized by its highly indented coast and large number of islands and islets, creating permanent challenges for surveillance and monitoring. This geomorphology complicates not only technical coverage but also legal clarity, as shown in dispute over Piran Bay, which underscores how natural coastal configurations intersect with questions of sovereignty.

The hydrometeorological literature provides critical insights into the Bora and Sirocco winds, which directly affect maritime operations. The Bora, a cold and gusty wind from the northeast, introduces instability and operational risk, while the Sirocco, a moist southeasterly wind linked to cyclonic activity, produces reduced visibility and hazardous sea states. Both winds have been shown to degrade the reliability of radar and optical surveillance, introducing environmental uncertainty into an already complex geomorphological setting.

Comparative material includes research on other semi-enclosed and indented seas. The Baltic and Aegean Seas illustrate how geographic constraints and overlapping jurisdictions complicate surveillance, while the Strait of Hormuz exemplifies a chokepoint where geomorphology and geopolitics converge. These cases are used as analytical mirrors to situate the Adriatic, underscoring both the commonalities and the distinctiveness of Croatia's maritime challenges.

Together, these materials constitute a layered foundation for the analysis. Legal sources define the framework of governance, technical and environmental studies reveal the natural constraints, Adriatic-focused literature provides regional specificity, and comparative cases situate the Croatian experience within a wider category of maritime surveillance environments.

The concept and features of semi-enclosed seas

According to the United Nations Convention on the Law of the Sea, "...a closed or semi-enclosed sea means a gulf, basin or sea surrounded by two or more States and connected to another sea or ocean by a narrow outlet or consisting wholly or primarily of the territorial seas and exclusive economic zones of two or more coastal States." (UNCLOS, 1982).

Coastal states bordering a closed or semi-enclosed sea should cooperate with each other in exercising their rights and fulfilling their duties under the Convention. To this end, they endeavor, directly or through an appropriate regional organization:

- To coordinate the management, conservation, exploration, and exploitation of the living resources of the sea;
- To coordinate the exercise of their rights and the fulfilment of their duties with respect to the protection and preservation of the marine environment;
- To coordinate their scientific research policies and, where appropriate,
- To undertake joint programs of scientific research in that area.

Spatial features of semi-enclosed seas

A characteristic of semi-enclosed seas is limited communication with adjacent seas or oceans, in contrast to "semi-open seas" such as the North Sea or the China Sea or "open seas" with long undefined boundaries with the ocean, like the Andaman Sea.

As a result of the development, expansion and definition of international law of the sea, the specific characteristics of individual marine areas, the seabed and subsoil, and even the coast are increasingly taken into account when formulating new rules for the spatial features of semi-enclosed seas. The spatial features of selected semi-enclosed seas around the world are presented in Table 2.

Table 2.
Spatial features of selected semi-enclosed seas in the world

Ocean	Name of the sea	Continent	Area ($km^{2)}$	Volume (km^3)	Connection to oceans/seas	Countries with Sea Access
Pacific Ocean	1. Yellow Sea	Asia	380,000	17,000	East China Sea	3
	2. Sea of Japan		978,000	1.360,4000	Pacific Ocean	4
	3. Sea of Okhotsk		1.538,000	1.280,100	Pacific Ocean	2
	4. Gulf of California (Sea of Cortes)	North America	160,000	131,900	Pacific Ocean	2
Atlantic Ocean	5. Gulf of Mexico		1.550,000	2.332,000	Atlantic Ocean	3
	6. Gulf of St, Lawrence		155,000	30,200	Atlantic Ocean	2
	7. Hudson Bay		819,000	157,700	Labrador Sea	2
	8. Baltic Sea	Europe	386,000	21,700	Northern Sea	9
	9. Mediterranean Sea		2.501,5000	3.842,200	Atlantic Ocean	21
	10. Black Sea		422,000	547,000	Mediterranean Sea	7
	11. Adriatic Sea		131,000	330,000	Mediterranean Sea	8
Indian Ocean	12. Red Sea	Africa	450,000	215,600	Indian Ocean Mediterranean Sea	8
	13. Persian Gulf	Asia	241,000	6,000	Arabian Sea	7

Source: By the authors according to (Britannica, 2023; Lowe, 1990; Leppäkoski et al., 2009; Mikulski, 1981; Oguz, & Su, 2004; Sunko, 2024)

Semi-enclosed, marginal seas and the continental shelf can be classified in terms of their morphological structure into three different groups:

- Almost enclosed basins with very limited exchange with the open oceans (Baltic Sea, Mediterranean Sea, Black Sea, Red Sea, Arabian Gulf, Bohai Sea, Okhotsk Sea, Sea of Japan - East Sea),
- Partially enclosed basins with moderate interactions with the open oceans along one or two of their boundaries (North Sea, Yellow Sea, East China Sea, South China Sea) and
- Marginal seas that extend along continental margins and have strong interactions with the open oceans along two or three of their boundaries (northern marginal seas of the Indian Ocean, seas of outer Southeast Asia, marine areas around Australia and New Zealand) (Oguz & Su, 2004). The geographical locations of the world's semi-enclosed seas are shown in Figure 1.

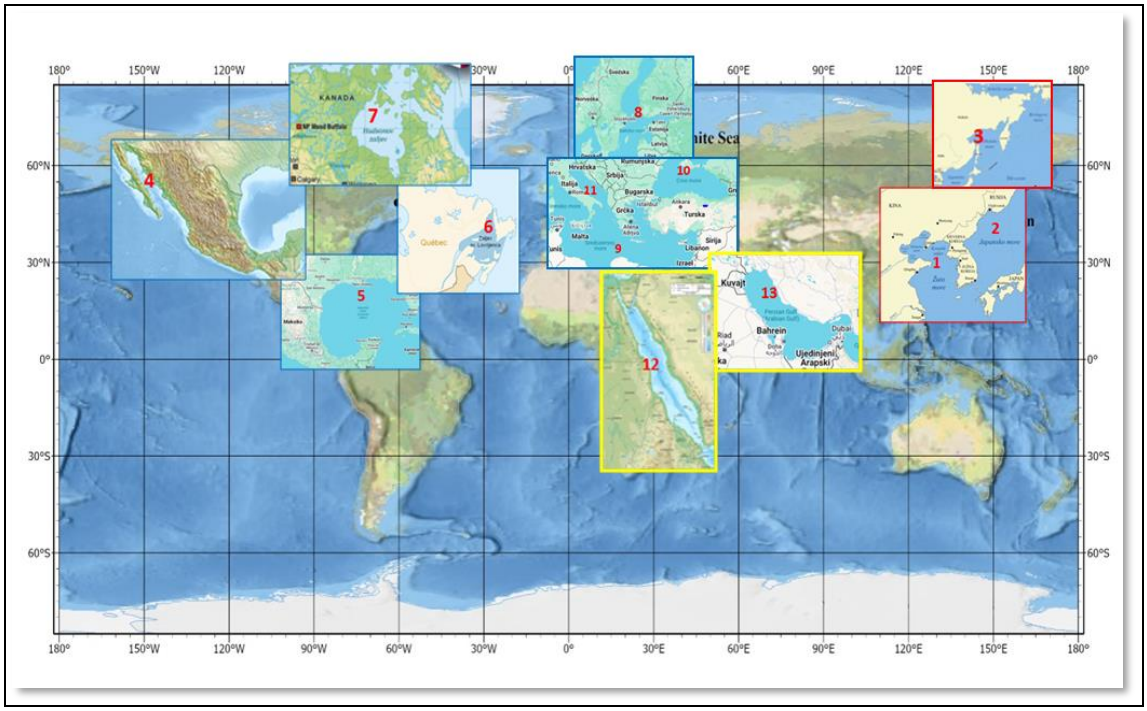

Figure 1. Geographical location of the world's semi-enclosed seas.
Source: By the authors according to (Britannica, 2023; Lowe, 1990; Leppäkoski et al., 2009; Mikulski, 1981; Oguz, & Su, 2004; Sunko, 2024)

According to Leppäkoski et al., (2009) semi-enclosed seas, due to their physical enclosure by landmasses and the strong influence of freshwater, tend to have lower salinity. For this reason, semi-enclosed seas are sometimes referred to as “brackish water islands”. The emphasis in the remainder of this work is on the eastern part of the Adriatic Sea.

Geographical features of the eastern part of the Adriatic Sea

The Adriatic Sea is a vast and elongated gulf in the eastern part of the Mediterranean Sea, bordered by the Apennine, Alpine, Dinaric, and Hellenic mountain ranges. It is located in the subtropical semi-arid zone of the southern part of the Northern Hemisphere and represents the northernmost indented part of the Mediterranean Sea into the European mainland and reaching up to φ = 45°47′ N (Leppäkoski et al., 2009). It stretches in a northwest-southeast direction (parallel to the orientation of the land relief and islands, between longitudes λ=012°15' E and λ=019°45' E and latitudes =39°45' N and 45°45' N) (Jardas et al., 2008; Croatian Hydrographic Institute, 2012). The southernmost point of the Adriatic is located at geographical coordinates: 40°07’ N and λ = 018°31’ E in the Strait of Otranto, and the northernmost at = 45°47’ N and λ = 013°35’ E near Derina, the RI (Jardas et al., 2008). Entry and exit into the Adriatic Sea begins and ends in the Strait of Otranto, the southern boundary of the Adriatic Sea. According to the International Hydrographic Organization - IHO, the boundary between the Adriatic and Ionian Seas is the line connecting the Butrintit River (southern coast of Albania, φ = 39°44′ N), Cape Karagol (island of Corfu, φ = 39°45′ N), via Cape Kefali (Corfu) to Cape Santa Maria di Leuca (Vrdoljak et al., 2021). The Strait of Otranto in its narrowest part is 75 km wide (41 nautical miles), with a maximum depth of 741 m (Riđanović & Bičanić, 1993; Žabica, 1993). The greatest length of the Adriatic Sea along its longitudinal axis in the northwest-southeast direction, measured from the Marano Lagoon (Porto di Lido, Venice) in the

north to the mouth of the Butrintit River in the south, is 870 km or 470 M. The width of the Adriatic Sea along its transverse axis, measured from east to west, from the port of Omiš to the port of Vasto (RI) is 117 M (216.7 km). The average mean width of the Adriatic Sea is 86 M (159.3 km). The deepest point of measured depth in the Adriatic was measured in the southern part on the Fasano - Budva cross-section, in the South Adriatic Basin, and it measures 1,233 m. The average depth in the Adriatic Sea is 252 m (Vokić Žužul & Filipović, 2015). In Figure 2, the bathymetric division of the Adriatic Sea is visible.

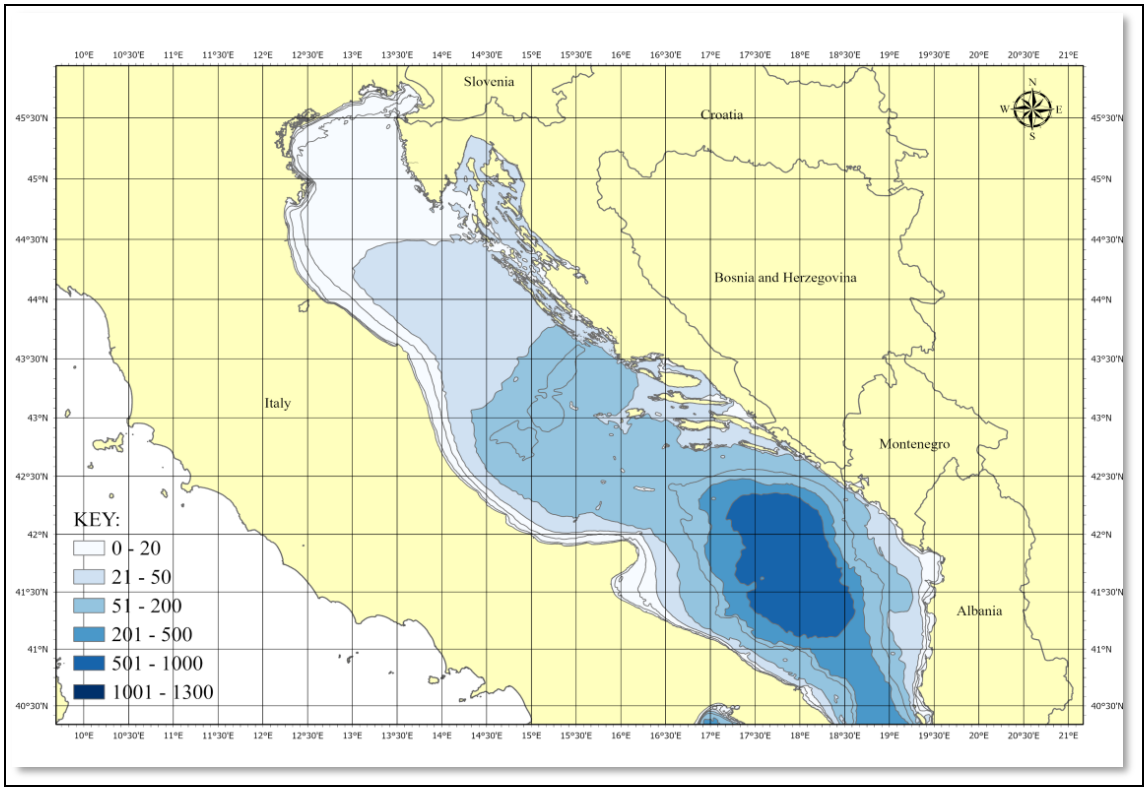

Figure 2. Bathymetric division of the Adriatic Sea.
Source: By the authors according to (Sunko, 2024; Vrdoljak et al., 2021)

Bathymetric analysis, including depth statistics, area and volume calculation, proves that the Adriatic is a shallow sea with an average depth of 253 m, with over 50 % of its surface shallower than 100 m. The Adriatic Sea can be considered according to its bathymetric and geographical divisions.

According to bathymetry, the Adriatic Sea is divided into three sub-basins:

- The Northern (extends to the line connecting the cities of Ancona and Zadar),
- The Central (extends between the Ancona - Zadar line and the line connecting Cape Gargano - Mljet Island - Pelješac Peninsula) and
- The Southern sub-basin (extends from the boundary line of the Palagruža Sill to the southern boundary of the Adriatic in the Strait of Otranto) (Vrdoljak et al., 2021).

Geographically, the Adriatic Sea is divided into three units:

- The Northern region includes the shallow northern Adriatic and extends to the line connecting Ancona and Karlobag,
- The Central Adriatic extends between the Ancona-Karlobag line and the line connecting Cape Gargano, Palagruža, Lastovo, Makarska, and Ploče,
- The Southern Adriatic extends from the Palagruža Sill to the Adriatic boundary at the Strait of Otranto (Marelić, 2016).

The Southern Adriatic, due to the open sea around the islands of Vis and Lastovo and around smaller islands (Palagruža, Svetac, and Jabuka), represents TS, which occupies the largest share of the total area of RC.

The western coast of the Adriatic Sea encompasses RI, and the eastern coast of the Adriatic Sea encompasses RC, Slovenia, Bosnia and Herzegovina, Montenegro, and Albania (Vokić Žužul & Filipović, 2015).

Hydrometeorological features of the Adriatic Sea

The Adriatic Sea is a moderately warm sea. In the Croatian part of the Adriatic, winds of great frequency are Bora (bura), Sirocco (jugo), and Mistral (maestral). The highest wind speed measured on the territory of the RC was recorded in December 1998 on the Maslenica Bridge when a Bora gust reached 248 km/h (69.0 m/s) (Croatian Hydrographic Institute, 2012; Volarić & Nikolić, 2014). The Northern Adriatic is an area with a very high frequency of Bora winds, while Sirocco is less represented. Generally, the intensity of the Bora decreases from the northern to the southern Adriatic, while the intensity of the Sirocco increases from the south to the north of the Adriatic, given that the windward direction coincides with the direction of the Adriatic Sea (SE). In March 1974, the strongest Sirocco gust of 205 km/h (56.9 m/s) was measured on Palagruža. Sirocco and Bora blow with the greatest intensity, with Sirocco developing higher waves than Bora. Mistral blows at a moderate strength and does not create waves dangerous for navigation, and usually blows from the western quadrant (WNW to NW direction), depending on the orography. In the winter period, Bora (NNE to ENE direction), due to its gustiness, represents an extremely dangerous wind for navigation, especially in the Velebit Channel area. Sirocco (ESE to SSE direction) blows with less intensity, but creates larger waves, given that the direction of Sirocco coincides with the direction of the Adriatic, thus creating enough windward area for waves to achieve full development. Until now, the highest wave in the Adriatic was officially confirmed at 10.8 m, measured in February 1986 on the PANON platform on the open sea of the northern Adriatic, also during a stormy Sirocco. However, the latest data indicate that the Croatian Hydrographic Institute measured a new maximum wave height on November 12, 2019, at 16:00. This wave was recorded in the waters of the city of Dubrovnik near the islet of Sv. Andrija. The maximum wave height was Hmax = 10.87 m with a corresponding significant wave height Hs = 4.75 m. On the eastern coast of the Adriatic, fog most frequently occurs on the western coast of Istria, on average 8 days a year, while in the rest of the Adriatic, the occurrence of fog is much lower. The average speed of sea currents is around 0.5 knots. In Table 3 the maximum wind gusts [speed (m/s), direction and missing monthly data, for 2024 from 11 automatic meteorological stations along the eastern coast of the Adriatic are presented.

Table 3.
Maximum wind gusts for 2024 from maritime meteorological stations

MAXIMUM WIND GUSTS (m/s)													
mjesec	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**god**
Poreč	33,4	26,3	26,5	32,5	22,4	23,5	23,7	22,0	25,8	-	-	33,6	**33,6**
	E	SE	SE	NE	ENE	ENE	NW	NNW	NNE	-	-	ENE	**ENE**
			2						2	744	720		1466
Rijeka	21,6	21,7	17,0	19,1	13,7	21,6	19,4	17,2	17,0	-	-	26,7	**26,7**
	NNE	SSE	E	ENE	WSW	NNE	NE	NNW	E	-	-	NNE	**NNE**
										744	720		1464
Senj	35,6	23,4	20,0	18,6	23,5	27,0	24,2	26,5	29,2	32,0	33,6	29,3	**35,6**
	NNE	E	NE	NE	NE	ENE	E	NE	NNE	NE	E	NNE	**NNE**
			418	588			19					3	1028
Mali Lošinj	17,8	-	22,3	21,2	20,	16,2	17,7	25,8	25,3	-	-	33,5	**33,5**
	NE	-	SSE	SSE	SW	SE	NW	NNW	W	-	-	NE	**NE**
		696					250			744	720		2410
Maslenički most	32,1	26,6	23,4	20,6	24,0	18,1	29,2	18,3	29,2	34,1	-	-	**34,1**
	NNW	NNE	N	E	WNW	N	NW	ESE	NW	N	-	-	**N**
			4				167	30		113	720	744	341
Zadar	16,9	25,5	20,6	23,0	19,4	15,2	18,3	25,3	17,6	19,1	20,1	24,2	**25,5**
	ESE	SE	SE	S	ESE	ESE	SSE	SW	W	SSE	SSE	NE	**SE**
		2	28		1	2			165	58			256
Split	27,6	24,8	30,1	31,8	24,2	18,6	19,0	16,6	23,8	17,8	24,7	29,1	**31,8**
	ENE	SE	SE	SE	SE	SW	NW	WSW	NE	SW	SSE	ENE	**SE**
					3	8		11	5	24		37	78
Hvar	22,0	-	25,5	27,1	20,4	15,5	15,8	13,3	19,6	21,3	22,5	22,9	**27,1**
	NE	-	ESE	ESE	ESE	ESE	ENE	NE	SW	SE	SSE	NE	**ESE**
		696				3		11		1			711
Vis	27,0	-	-	26,8	26,4	19,1	21,5	28,3	22,2	26,8	-	30,6	**30,6**
	SE	-	-	ESE	ESE	NW	NW	NNW	WNW	ESE	-	ESE	**ESE**
	34	696	744	99	38	89	17	156	163	11		40	1440
Palagruža	25,7	-	29,8	20,5	21,9	15,9	26,5	20,4	11,0	-	-	-	**29,8**
	SE	-	WNW	S	SSE	SSE	NW	SW	NNW	-	-	-	**WNW**
	88	696				396			660	744	720	744	4058
Dubrovnik	29,4	26,8	26,0	22,3	20,8	18,5	25,3	21,3	24,7	25,9	25,1	29,7	**29,7**
	NNE	SSE	SE	SE	NE	SE	WNW	SSE	SE	ESE	NNE	NNE	**NNE**
						3							3

Source: By the authors according to (Državni hidrometeorološki zavod, 2024)

As can be seen from Table 3., automatic measurement of wind speed is not the most reliable way, given the number of missing data.

Relationship of semi-enclosed sea features to maritime surveillance and security

Geomorphological features of the coastline, position of the surrounding states and the indentation scale of the coastline heavily influence national and regional surveillance and security policies in both legal and technical sense (Fuglesang Rye, 2021; Hayton, 2014; Do, 2024; International Crisis Group, 2025; International Maritime Bureau, 2019; Nyman et al., 2010; Pugh, 1994; Scovazzi, 2024; van Dyke, 2005). To establish a link between geomorphology of semi-enclosed seas and the problematic of surveillance and security, real life examples of various regional legal and technical challenges across the world are examined, analysed and taken into account. Problems, as well as characteristics of said problems are analysed in the following regions of the world that could be classified as semi-enclosed seas or indented areas: Nordic Fjords (Fuglesang Rye, 2021), South China Sea (Hayton, 2014), pacific island states (Do, 2024) and Philippines (International Maritime Bureau, 2019), although not directly classified as semi-enclosed maritime area, do poses similar problems for similar reasons, Strait of Hormuz and the Persian Gulf (International Crisis Group, 2025), Baltic Sea (Nyman et al., 2010), Mediterranean (Scovazzi, 2024) and the Aegean Sea (van Dyke, 2005). Nature of said problems are thereby classified into legal or technical category (or both), main problem is listed and the cause of the problem is assessed. The summation of analysed problems yields a concrete link between the nature of semi-enclosed seas and the challenges that arise organically due to it.

Table 4.
Comparison of problems concerning semi-enclosed and indented seas by region

Region	Problem	Problem category (legal/technical/both)	Cause of the problem
Nordic fjords	Radar surveillance diminished	Technical	Complex geomorphology (complex terrain), hydrometeorological nuisances
South China Sea	Border disputes, grey zone tactics	Legal	Complex geomorphology, lack of cooperation
Pacific island states	Maritime crime and grey zones (lack of surveillance)	Technical	Complex geomorphology, lack of cooperation
Persian Gulf	General maritime security, asymmetric attacks	Both	Geomorphology (chokepoint, high traffic), regional instability
Philippines	Increased piracy due to AIS and radar gaps and blind spots	Technical	Complex geomorphology (multitude of islands)
Baltic Sea	Surveillance betterment needed, high risk of collisions to both human life and environment	Technical	Complex geomorphology
Mediterranean Sea	Lack of protection for underwater heritage sites, problem of navigation in environmentally sensitive areas	Legal	Lack of cooperative framework
Aegean Sea	Border disputes, traffic surveillance rights and right of passage questioned by contesting states	Legal	Complex geomorphology, lack of cooperation

Source: By the authors according to (Fuglesang Rye, 2021; Hayton, 2014; Do, 2024; International Crisis Group, 2025; International Maritime Bureau, 2019; Nyman et al., 2010; Scovazzi, 2024; van Dyke, 2005)

As visible in Table 4, all problems fall under either legal or technical category. Majority of them are due to complex geomorphology, i.e. steep and uneven terrain, fractal like nature of fjords, multitude of islands with multitude of blind spots present; hydrometeorological circumstances, such as frequent storms or high winds that disrupt the reflection pathway of electromagnetic radar waves and, as such, cause distortions in radar image; and regional instability due to border disputes, ongoing geopolitical tensions and conflicts as well as differing interests, made even more complex by the number of contesting entities on a limited natural resource base (hence, a term “chokepoint” is etymologically linked with overcrowding), intertwined with hardship presented by the sheer number of islands and similar features present especially in an indented coastal areas. The number of entities tasked with collective governance of a relatively narrow geographical area also induces challenges with respect to regional cooperation. To summarize, all semi-enclosed seas and indented or indented-like coastlines and areas share similar problems with surveillance and security that can be either legal or technical, and caused by either lack of cooperation, complex geomorphology or hydrometeorological circumstances, or combinations of said. To further simplify the systematization of challenges for semi-enclosed seas, a diagram is provided in Figure 3.

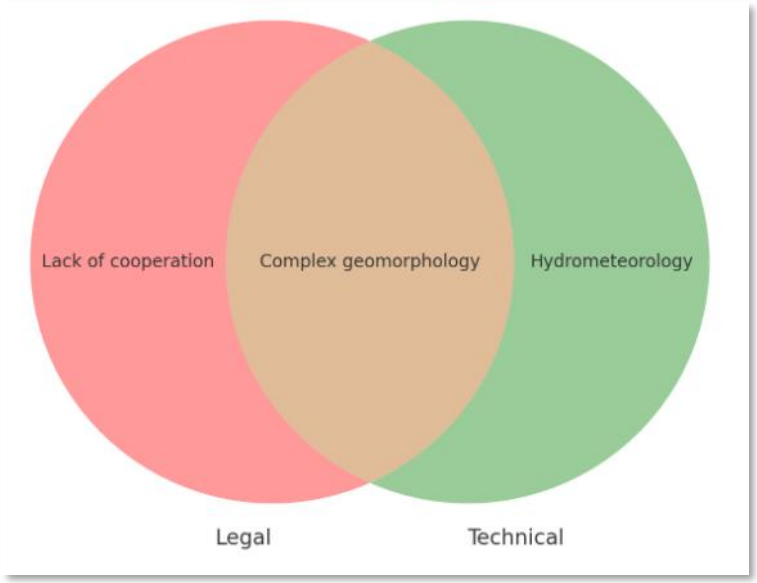

Figure 3. Systematic view of the challenges of maritime security and surveillance of semi-enclosed seas with regards to the challenge category and cause. Source: By the authors

Results and discussion

The Adriatic Sea exhibits two distinctly different coastlines: a poorly indented and almost islandless western coast and a highly indented eastern coast with numerous islands. The total length of the Adriatic coastline is 8,282 km. The RC has the longest land coastline in the Adriatic Sea (48 % of the total land coastline of the entire Adriatic). The land coastline is 1,880 km long (29.9 % of the total land coastline of the RC). The length of the island coastline can be divided into: coastline of islands (3,573 km), coastline of islets (717 km) and coastline of reefs and rocks (107 km).

The total length of the coastline belonging to all islands, islets, reefs and rocks in the eastern Adriatic Sea in the RC is 4,398 km (70.1 % of the total island coastline of the RC; 97.2 % of the total length of island coastlines in the entire Adriatic). The total length of the Adriatic Sea coastline of RC is 6,278 km (75.8 % of the total length of the coastline of states in the Adriatic Sea). In terms of coastline length, the RC is the third country in the Mediterranean, after the RG and the Republic of Italy. The total marine area of the Adriatic Sea is 138,595 km² (accounting for 5.5 % of the total area of the Mediterranean Sea including island areas, and excluding the islands, the area is 135,418 km2) (Jardas et al., 2008). The marine area of the Adriatic Sea of the RC is divided into: the area of internal waters (12,498 km²), territorial sea (18,981 km²) and exclusive economic zone (23,870 km²).

The Adriatic Sea has a volume of 34,836 km³. The external boundary of the TS also represents the RC's maritime border. The total area of all islands, islets, reefs and rocks in the RC's Adriatic Sea is 3,259 km2. The RC has 1,246 islands, islets, reefs, and rocks, including 79 islands, 525 islets, and 642 reefs and rocks. Cres Island has the largest area (405.70 km²), while Smokvica Vela (Kornati) has the smallest (1.04 km²). The islet Badija has the largest area (0.97 km²), while Galicija islet has the smallest (0.01 km²). The island of Pag has the longest coastline (302.47 km), while Vele Orjule Island has the shortest (5.89 km). Among the 79 large islands with an area exceeding one square kilometre, 66 are inhabited; 525 are islets with an area of 0.01 km² to one km²; and 642 are reefs and rocks with a total area of less than 0.01 square kilometres (Leder et al., 2004) The eastern Adriatic coastline, belongs among the most indented sea coasts in the world, and after the RG coastline, it is the most indented in the Mediterranean (Riđanović & Bičanić, 1993).

Marine and submarine area of the eastern part of the Adriatic Sea

According to Article 2 of the Constitution of the RC and the Maritime Code (Zakon Hr, 2019), the sovereignty of the RC at sea extends to its IW and TS, the airspace above them and their seabed and subsoil. In accordance with international law, the RC exercises sovereign rights and jurisdiction over the marine areas and seabed of the Adriatic Sea beyond the state territory up to the borders with neighbouring countries

through its EEZ and CS. The CS of the RC covers 44,844 km² (Sea Around Us, 2016). Waters from the baseline of the TS towards the land are considered to be part of the state's internal waters. States exercise full sovereignty over their IW, and IW is legally equivalent to land territory. The IW of RC include ports and bays along the mainland and island coast (Figure 3), as well as parts of the sea between the low-water line on the mainland coast and the straight baseline used to measure the width of the TS. Coastal state sovereignty extends beyond its land territory and IW to the adjacent belt of sea known as the TS. Every state has the right to establish the breadth of its TS up to a not exceeding 12 M, measured from the baselines determined in accordance with the United Nations Convention on the Law of the Sea. States exercise sovereignty in their TS, with the exception of the right to innocent passage, which is guaranteed by the Convention.

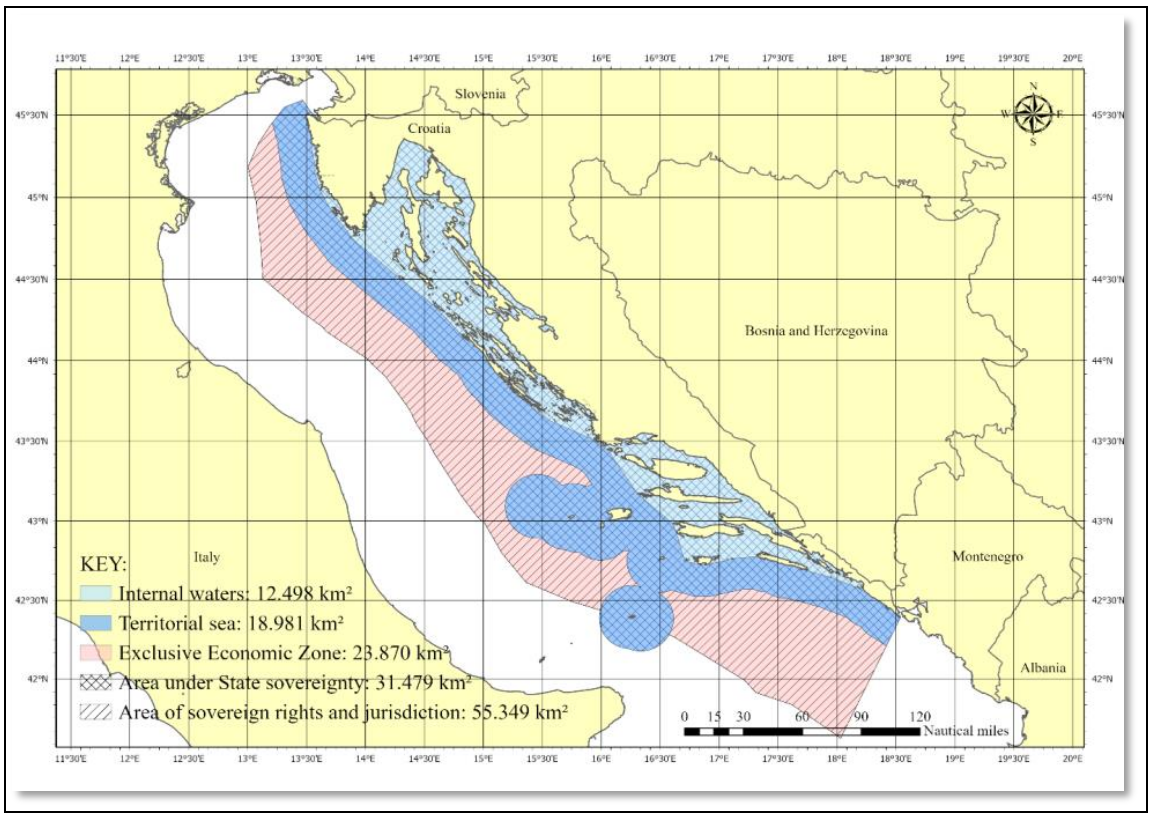

Figure 4. Marine and underwater areas of the Republic of Croatia in the Adriatic Sea.
Source: By the authors according to (Sea Around Us, 2016; Sunko, 2024)

In February 2021, the Croatian Parliament declared the EEZ of the RC in the Adriatic Sea in accordance with the United Nations Convention on the Law of the Sea, within the legal framework established in Part V of the United Nations Convention on the Law of the Sea and Chapter IV (Decision on the Declaration of the EEZ of the RC in the Adriatic Sea). The EEZ of the RC encompasses the maritime space extending from the outer boundary of the territorial sea in the seaward direction to its outer boundary permitted by general international law (Narodne novine, 2021). The outer boundaries of the EEZ of the RC will be determined through international agreements on delimitation with countries whose coasts lie opposite or adjacent to the RC, which has not been done to date. In October 2022, within the framework of the fifth meeting of the Coordinating Committee of the governments of RC and RI, a Treaty on the delimitation of the EEZ between RC and RI was signed. The treaty mutually determines the line of delimitation of the EEZ between the mentioned states, in accordance with international law. The line of delimitation of the EEZ is the already existing line of delimitation of the CS on the seabed and subsoil (Vlada Republike Hrvatske, 2022). The application of the legal regime of the EEZ of RC from Chapter IV. of the Maritime Code is carried out in accordance with Part V of the Convention and the legislation of the European Union. Unlike the EEZ, the rights of the coastal state to the CS do not depend on actual or fictitious occupation, nor on any explicit proclamation of the sea. For this reason, RC did not proclaim its CS in the way the EEZ was proclaimed, by decision of the Croatian Parliament (Narodne novine, 2021).

Fairways, separated and directed navigation systems in the Adriatic Sea

Due to its natural features, longitudinal, transverse, and coastal navigation routes have been established in the Adriatic Sea (Figure 4). The most important longitudinal navigation route in the open sea of the Adriatic Sea, takes place in a northwest-southeast direction, and represents the shortest sea distance between the Strait of Otranto in the southeast and maritime ports located in the northwest part of the Adriatic Sea.

Along the most important central navigation route in the open sea of the Adriatic, longitudinal navigation routes have been formed:

- Along the western coast of the Adriatic Sea (Strait of Otranto - Cape Gargano - traffic separation scheme of Ancona) and close to the the coast,
- Along the eastern coast of the Adriatic Sea, along the outer edge of a series of islands in the northern and central part of the eastern Adriatic coast and along the eastern coast of the Adriatic Sea,
- Along the inner edge of the outer series of islands.

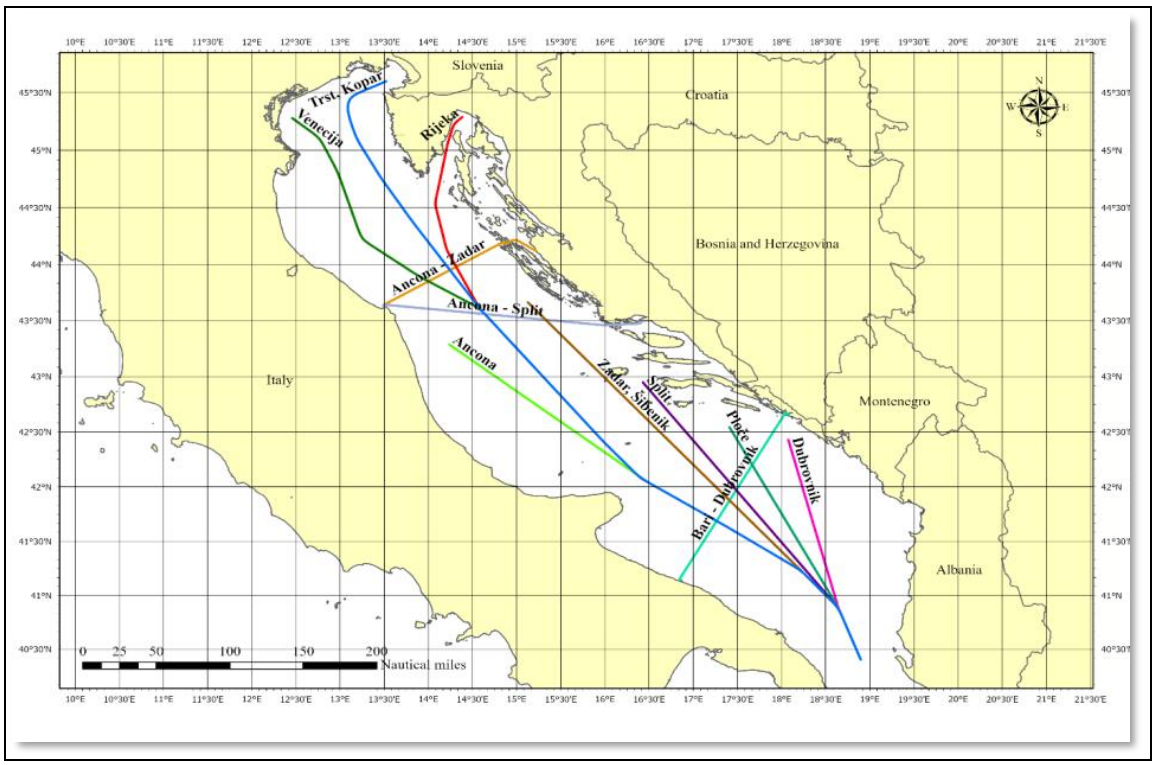

Figure 5. The main longitudinal and transverse navigation routes in the Adriatic Sea.
Source: By the authors according to (Sunko, 2024)

If hydrometeorological conditions (wind and waves) permit, navigation routes are most often established according to the criterion of the shortest distance. Along the immediate vicinity of the western (coast of the RI) and eastern (coast of Albania, Montenegro, RC and Slovenia) lines of the Adriatic Sea coastline, coastal navigation routes have been established. The vessel traffic routing scheme in the Adriatic Sea was approved by the IMO) in 2001 and has been in effect since 2002. In 2004, the IMO's Maritime Safety Committee adopted new and amended vessel traffic separation schemes and measures for routing navigation in the Adriatic Sea, which came into force in 2004 (Luttenberger & Zec, 2010). The system of directed and separated navigation for the area of the northern Adriatic was adopted at the IMO Marine Environment Protection Committee session MSC.139 (76) in 2006 (International Maritime Organization, 2006) and was published in NtM (Ćorić & Šantić, 2012; Hrvatski Hidografski Institut Split, 2007; Sveučilište u Rijec, 2016; Kos, 2018). Navigation is regulated by a separation scheme and reporting obligations with defined temporal and spatial components for the entry of ships into the Adriatic Sea. Between Pianosa Island on the Italian side and Palagruža Island on the Croatian side, within the boundaries of the territorial sea of RC, there is a vessel traffic separation scheme for the central Adriatic.

Navigation features of communication coverage of the Adriatic Sea

Due to the indented coastline, natural and artificial objects on the coast and at sea, numerous islands, islets, shoals, reefs, narrow passages, sea straits and channels, the eastern coast of the Adriatic Sea is ideal for using terrestrial navigation methods to determine the position of a ship. Terrestrial navigation in the Adriatic Sea is complemented by radar and satellite navigation (Sveučilište u Rijec, 2016). All components that enable orientation at sea and determination of the position of a ship in all navigation conditions represent the navigational features of a specific navigation area. Navigational support for ships in navigation enables the determination of ship positions, course and speed. All navigational features imply technological support.

With the establishment of the CROPOS system in 2008, the condition for the application of new geodetic datums and cartographic projections of the RC was met. The positional and altitude transformation accuracy in the area of continental RC was ±0.05 m and in the area of the Adriatic Sea ±0.10 m (Marjanović, 2011). The CROPOS system enabled real-time positioning with an accuracy of ±2 - 4 cm in the entire area of the RC (Premužić et al., 2018). The network solution of the CROPOS system currently includes 56 reference stations. The positioning service in the Adriatic Sea - eastern part is also offered by mobile telephone networks (Republika Hrvatska, 2024).

In accordance with the GMDSS, the Adriatic Sea - eastern part falls under the A1 Sea area in which the RC is obliged to provide coverage with a: VHF belt, through DSC and NAVTEX.

The basic terrestrial wireless networks for the needs of regular communication (voice and data transmission), safety, urgency and distress are defined by the frequency range they use. In the area of the Adriatic Sea - eastern part, four VHF simplex channels are mandatory (06, 13, 16 and 70). On VHF channel 16 (156.800 MHz) the watchkeeping service, calling and communication in case of distress and safety by radiotelephony, coordination of SAR actions and for providing other communication services are carried out. As part of radio traffic, ships navigating the eastern Adriatic Sea can also utilise CRSs of RC. All communications are carried out via the working channels of CRSs of the RC (Rijeka radio, Split radio and Dubrovnik radio). During navigation, constant ship radio – watchkeeping is organized on: VHF DSC channel 70, MF DSC frequency 2187.5 kHz, on MF/HF DSC frequencies (8414.5 kHz and on one of the following frequencies: 4207.5 kHz, 6312 kHz, 12577 kHz or 16804.5 kHz) or by means of INMARSAT ship station, and watchkeeping on VHF channel 16. The automated NAVTEX service of direct printing of navigational notices, maritime safety information, navigational and meteorological warnings, meteorological forecasts and other urgent safety messages to ships is part of the GMDSS system. NAVTEX messages are broadcast in the working frequency range of 518 kHz (international NAVTEX service) and 490 kHz (national NAVTEX service). The Croatian Hydrographic Institute is the national coordinator of the NAVTEX system in RC.

Surveillance and security challenges on the eastern part of the semi-enclosed Adriatic Sea

As presented in the previous section, challenges characteristic to semi-enclosed seas can be divided into either legal or technical category, with causes that influence them being either complex geomorphology, hydrometeorological circumstances or lack of cooperation. Although this systematization has been gathered by analysing problems occurring in semi-enclosed seas or similar geomorphological locations across the world, it is now used to classify problems of eastern Adriatic coast and thus crate a connection between challenges that occur and the nature of semi-enclosed seas.

One of the problems that arises in the eastern Adriatic is the malfunction of radar surveillance systems and EO/IR (Electro-optic/infrared) surveillance equipment. The mail cause of the these problems are arising from the adverse weather conditions (Cosoli et al., 2010; Vujović & Kuzmanić, 2018). Electro-optical devices can be interfered with due to storms, hales, fog and rain, but also due to reflections of the sea surface, which can be especially challenging during high seas (Vujović & Kuzmanić, 2018). As the Sirocco wind, which is one of three main winds occurring in eastern Adriatic and which blows mostly in late winter period (January-March) is often considered the one causing storm surges and high waves due to it's connection to the locations of cyclogenesis, as already discussed in previous section (Lionello et al., 2012). Therefore, it is to be expected that during this period EO/IR surveillance will be hindered the most. The problem of radar surveillance hinderance has not been directly tested on eastern Adriatic, however problems due to adverse weather did occur when a specific study was conducted using a shore-based high-frequency (HF) radar in northern Adriatic (Cosoli et al., 2010). The cause of the hinderance of the radar surveillance

is listed as the pulses of northeasterly wind, that is Bora, characteristic for it's high intensity in northern Adriatic especially, but as discussed in previous section, not uncommon within northern and mid part of the eastern Adriatic as well (Cosoli et al., 2010). All of these challenges can be described as caused by the specific hydrometeorological circumstances of semi-enclosed seas, such as Adriatic, and can be classed as technical problems in nature.

Another problem that arises on eastern Adriatic coast is a border dispute of Piran bay. The arise of dispute is at the same time complicated and simple. The Slovenian government claimed the corridor of Piran bay as part of it's inside waters, as opposed to Croatian territorial sea, in order to gain access to international waters (Degan, 2019). Similarly to one of many disputes arising in the Aegean Sea between Turkey and Greece discussed in previous section, main dispute arose from the unclear demarcation of the continental shelf (Degan, 2019; van Dyke, 2005). Although this problem has been subsequently solved, albeit after almost 30 years of dispute, unclear demarcation may cause an unclear authority on the location and therefore a threat to security. This challenge can, according to established systematization, be classified as legal and the causes of it complex geomorphology (unclear continental shelf demarcation) and lack of cooperation.

As eastern Adriatic is characterized by an indented coastline, mapping and creation of interactive charts can heavily simplify surveillance and surveillance planning. For this reason, in recent years there has been an increasing number of attempts to utilize GIS (Geographic Information System) to improve surveillance and security and also to solve legal issues of concessions, borders etc. However, this process is slowly implemented and still fragmented and not unified, creating possible gaps in surveillance and especially surveillance planning and maritime spatial planning as a whole (Kovačić et al., 2022). This issue is both technical and legal, legal in the sense that maritime spatial planning lack national framework and is caused by primarily complex geomorphology.

Some of the major problems regarding security and surveillance of eastern Adriatic can be directly correlated with the general geographic specifications of semi-enclosed seas. Simplified version of the analysis is provided in Table 4:

Table 5.
Analysis of problems arising in eastern Adriatic by systematization of challenges typical for semi-enclosed seas (Table 4)

Problem	Cause (hydrometeorology/ complex geomorphology/ lack of cooperation)	Category (legal/technical/both)
Electro-optical/radar surveillance difficult	Hydrometeorology	Technical
Pyran bay border dispute	Complex geomorphology, lack of cooperation	Legal
GIS system fragmented	Complex geomorphology	Both

Source: By the authors according to (Cosoli et al., 2010; Degan, 2019; Kovačić et al., 2022; Vujović & Kuzmanić, 2018)

Conclusion

Timely identification of processes and phenomena that can disrupt the security and interests of coastal states in semi-enclosed seas requires a multifaceted approach, recognizing events and occurrences in an environment of increased risks from illegal activities. In the context of the spatial distribution of systems and subsystems for controlling and protecting the rights and interests of coastal states in semi-enclosed seas, understanding the spatial structures of semi-enclosed seas is very significant. The spatial structures of controlled and protected maritime areas can significantly influence security strategies, control capabilities and protective measures. With the aim of more effective implementation of control and more efficient protection of the rights and interests of coastal states, there is a recognised need for an analysis of the spatial features of semi-enclosed seas. Physical-geographical features, and the environment of the coastal area is extremely important in the process of positioning control and protection systems, and thus reducing possible risks. Islands can serve as strategic points for monitoring outposts, radar installations and military maritime locations in order to improve the ability to track and respond to possible illegal activities.

The spatial features of semi-enclosed seas have been considered from several different perspectives to ensure an integrated approach that provides recommendations and guidelines for placing control and protection systems. Understanding spatial features and their implications is extremely important for the development of effective maritime security measures. By ensuring the security of maritime assets, coastal states protect their economic prosperity, environment and overall national security. In line with this, the paper conceptually and systematically presents the results of research on the spatial features of the semi-enclosed Adriatic Sea - eastern part. All geographical, marine, submarine, navigational, hydrometeorological and navigational features of the Adriatic Sea - eastern part were thoroughly studied and analysed. Previous relevant research was reviewed and a structural analysis of the determinants of national and international legal regulations by which the RC exercises jurisdiction in accordance with international law and national legal regulations in the Adriatic Sea - eastern part was performed.

Moreover, a comparison has been presented to other semi-enclosed seas worldwide, which constitutes that majority of the problems in security and surveillance arise from particular properties of said seas: complex geomorphology, hydrometeorology and lack of cooperation and can be classified as either legal or technical (or both). This systematization is them further applied to particular challenges on the eastern Adriatic, finding them to be in accordance with such systematization. This framework is developed not only to correlate properties of semi-enclosed seas with typical problems occurring in them, but also to be used in future to simplify problem-solving regarding these issues as well as aid future research regarding surveillance and security of semi-enclosed seas.

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