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Special Edition

ECORFAN Journal - Spain

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Knowledge Area

The works must be unpublished and refer to topics of education, crowdsourcing, operation of academics' corps, regional development, fiscal, architecture, networks and other topics related to Social Sciences.

Presentation of the Content

In volume eleven, issue twenty, as the first article we present, *Strategic approach to digital transformation in higher education institutions*, by Rivera-Gutiérrez, Erika, Higuera-Zimbrón, Alejandro and Argüello, Georgina, with secondment in the Universidad Autónoma del Estado de México, Nova Southeastern University, as a second article we present, *Integration of architecture and communication: a transversal learning methodology empowered by artificial intelligence tools*, by Grajeda-Rosado, Ruth María, Rosello-Luna, Alma Saraíb, Vázquez-Torres, Claudia Eréndira and Sotelo-Salas, Cristina, with an appointment at the Universidad Veracruzana, Universidad Autónoma de Yucatán, Universidad Autónoma de Baja California, as a third article we present, *Proposal of a conceptual matrix to present the state of the art of a research to based on the systematic literature review methodology*, by Mendoza-Ruiz, Irving, Antonio-Vidaña, Paula and Cabrera-Ortega, Kristal, with secondment at the Universidad Tecnológica del Centro de Veracruz, Secretariat of Public Education, as fourth article we present, *Megatrends as a factor of innovation and their influence on sustainability from a university perspective, Mexico*, by Salguero-Cruz, Yizel Carolina & Flores-López, José Guadalupe, with secondment at the Instituto Tecnológico de Sonora.

Content

Strategic approach to digital transformation in higher education institutions

Enfoque estratégico de la transformación digital en instituciones de educación superior

Rivera-Gutiérrez, Erika*[a], Higuera-Zimbrón, Alejandro[b] and Argüello, Georgina[c]

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Abstract

The research study titled *Strategic Exploration of Digital Transformation in Higher Education Institutions* aims to comprehensively analyze and understand the approaches higher education institutions are taking towards digital transformation. It takes a strategic approach to explore the conception, initiatives, challenges, and opportunities related to the adoption of digital technologies in this constantly evolving academic environment. The research results, obtained through a detailed review of existing literature in various specialized databases on digital transformation in higher education, indicate that higher education institutions are adopting diverse strategies for digital transformation. These strategies range from digitizing content to implementing online learning platforms. Common challenges are identified, such as resistance to change and the need for investment in technological infrastructure. Emerging opportunities are also highlighted, such as personalized learning and inter-institutional collaboration through technology. The study concludes by emphasizing the importance of solid strategic planning and adaptability in the digital transformation process. It suggests that higher education institutions should address the changing needs of students and leverage digital technologies effectively to improve the quality of teaching and learning. Ultimately, the research provides a valuable foundation for future studies and will guide the strategic decisions of educational institutions in pursuit of digital transformation.

Resumen

El estudio de investigación *Exploración Estratégica de la Transformación Digital en Instituciones de Educación Superior* se centra en analizar y comprender de manera exhaustiva cómo las instituciones de educación superior están abordando la transformación digital en la actualidad. Para este caso, se utiliza un enfoque estratégico que plantee su concepción, iniciativas, desafíos y oportunidades relacionadas con la adopción de tecnologías digitales en algunos entornos académicos en constante evolución. Se hace una revisión detallada de la literatura existente en diversas bases de datos especializadas sobre la transformación digital en la educación superior. Los resultados de la investigación indican que las instituciones de educación superior están adoptando diversas estrategias para la transformación digital, que van desde la digitalización de contenidos hasta la implementación de plataformas de aprendizaje en línea. También, se identifican desafíos comunes, como la resistencia al cambio y la necesidad de una mayor inversión en infraestructura tecnológica. Además, se destacan oportunidades emergentes, como la personalización del aprendizaje y la colaboración interinstitucional a través de la tecnología. Se concluye enfatizando la importancia de una planificación estratégica sólida y la adaptabilidad en el proceso de transformación digital. Se sugiere que las instituciones de educación superior deben abordar las necesidades cambiantes de los estudiantes y aprovechar las tecnologías digitales de manera efectiva para mejorar la calidad de la enseñanza y el aprendizaje. En última instancia, el estudio proporciona una base valiosa para futuras investigaciones y para orientar las decisiones estratégicas de las instituciones educativas en búsqueda de la transformación digital.

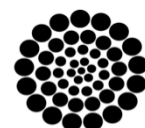Strategic Planning for Digital Transformation

Planeación Estratégica de Transformación Digital
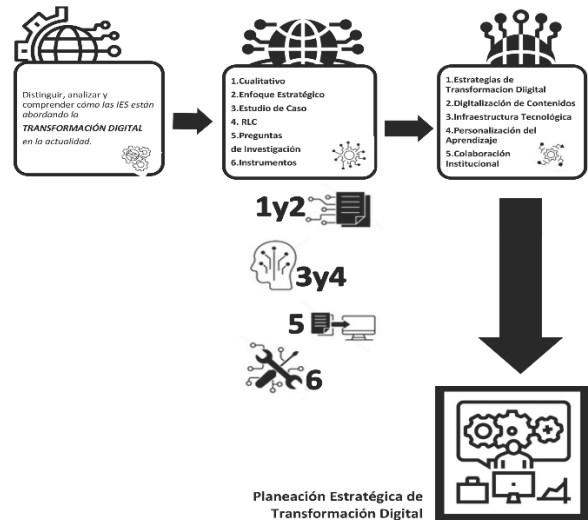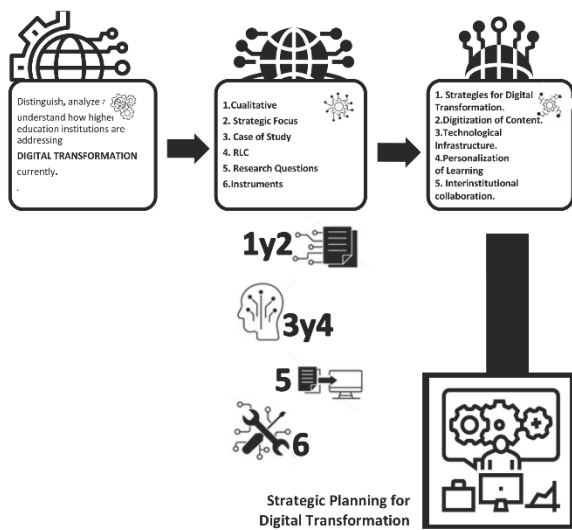
Strategy, Digital transformation, Education

Estrategia, Transformación digital, Educación

Article

Introduction

Today, higher education institutions (HEIs) have had to adapt to the fast-moving technological changes. With the passage of the Covid19 pandemic, HEIs have had to reinvent themselves in a systematic and permanent way in order to face the challenges of an ever-changing environment, the reality of the digital era. On the one hand, Information and Communication Technologies (ICT) have become essential tools for their transformation. On the other hand, ICT are an integral part of the fourth industrial revolution or industry 4.0, characterised by technological and digital advances that are transforming and impacting economically, in all productive sectors (industry, government, society and academia), such as automation, interconnection of devices, data analysis, artificial intelligence, adoption of the cloud, digital transformation, among others (Cabrera, et al., 2020). Hence, it is not only about HEIs advancing or evolving today, but also about their ability to anticipate the future. It is a fact that everything is changing, new professions, more holistic, multidisciplinary and transdisciplinary. In this sense, they must focus on a vision of a digital world, in which they are already immersed, but there is still a long way to go.

The digital transformation that is taking place in societies around the world has a direct effect on all productive sectors. Celis and Ramon (2023) mention that "technology used appropriately within organisations generates a great impact within them, an organisational culture oriented towards innovation and technological development" (p. 10), which allows them to continue to advance and grow. Therefore, it is clear that organisations, whatever their field of activity, need to transition to this digital transformation to take advantage of the capabilities that technologies provide them, changing their processes and promoting new organisational models to adequately incorporate themselves into the new digital scenario. In which most areas of human activity are being affected, giving rise to new challenges. Particularly, its impact on the educational sphere is highlighted, in higher education institutions, where this technological evolution has given rise to a re-evaluation of teaching-learning methodologies, access to information, as well as data management within universities.

Therefore, the objective of this study focuses on distinguishing, analysing and understanding how HEIs are carrying out the digital transformation both in their academic programmes and in their academic-administrative processes. The intention is, on the one hand, to identify the effective digital transformation strategies and practices they are implementing. On the other hand, to recognise the challenges and opportunities associated with the adoption of digital technologies in HEIs. To achieve this, this qualitative research applies a strategic approach to explore strategic initiatives and effective practices, and to analyse the challenges and opportunities associated with the adoption of digital technologies in the evolving university academic environment.

Case studies on digital transformation in higher education institutions are presented. The systematic review method is used to define the state of the art of the variable addressed, which makes it possible to delve deeper into the subject, contributing to its understanding, as well as to the relevance of the adoption of digital technologies in this academic environment that must remain in constant change based on the demands of society. In this sense, we start from the following questions *In what ways are HEIs undertaking digital transformation in both their academic programmes and their academic-administrative processes, what are the effective strategies and practices that HEIs have implemented for digital transformation, what are the challenges and opportunities linked to the adoption of digital technologies in HEIs, and what are the challenges and opportunities that are linked to the adoption of digital technologies in HEIs?*

Based on the above, the study was structured as follows: 1) identification of relevant studies, 2) selection of studies, 3) data extraction, and 4) analysis and discussion of findings. The search was conducted using the following databases *Web of Science*, *Science Direct*, *Google Scholar,* entre otras. Considerando como criterios: periodo del time from 2020 to 2023, open access scholarly articles.

Descriptors were applied in English and Spanish as: digital transformation, digital transformation in education, digital transformation in education., *digital transformation*, *educational digital transformation*. The study contains the following sections: first, it addresses digital transformation, as well as digital transformation in education, from its conception, characterisation and impact; second, the methodological design; and third, it presents the analysis and discussion of the findings. Finally, the conclusions of the study are presented.

Digital transformation

The use and application of new digital technologies has led organisations to transform their customer relationships, internal processes and value propositions, to develop models, software processes and business systems to improve both revenue profitability and competitiveness. In this sense, it is clear that as with any transformation process, it is necessary to generate major changes, breaking paradigms, where digital transformation is no exception, for everyone it represents a great challenge, therefore, we must work for it.

The Development Centre of the Organisation for Economic Co-operation and Development (OECD, 2019), for its understanding, points out that:

Digitisation (digitisation) is the conversion of analogue data and processes into a machine-readable format. Digitalisation (digitisation) is the use of digital technologies and data, as well as the interconnection that gives rise to new activities or changes in existing ones (p.18).

Accordingly, it mentions that "digital transformation refers to the economic and social effects of digitisation and digitalisation" (OECD, 2019, p.18). In other words, digital transformation incorporates the two previous concepts, taking into account the automation of activities and the development of a culture of automation and innovation. In addition to considering which processes or activities are necessary and those that should be eliminated by the substitution of the digital organisation. It should be noted that digital transformation refers to a change in everyone's way of thinking.

Digital transformation arises from the incorporation of new digital technologies called SMACiT: Social (social networks), Mobile (mobile devices), Analytics (data analysis), Cloud computing (cloud operations) and Internet of Things (Internet of things) (González, 2021). This transformation represents all kinds of challenges for the present and future of any organisation, through the integration of SMACiT and related technologies. Hence, digitally transforming an institution or organisation does not only imply digitising it. It is clear that it requires an organisational change where the actors involved, the processes, as well as the business model understand technology as a tool that generates value among its consumers and collaborators (Schwab, 2016).

Delgado (2021) argues that:

'Digital transformation is emerging as a topic of interest not only in scientific communities, but as increasingly recurrent practices in organisational dynamics, which are subject to the pressures imposed by disruptive technologies, new business models that manifest themselves throughout the value chain, and the personalised demands of users in an environment of hyperconnectivity' (p.1).

While, Demirkan et al. (2016), define it as:

'The profound and accelerated transformation of activities, processes, competencies and business models to take full advantage of the changes and opportunities provided by digital technologies and their impact on society in a strategic and prioritised way' (p. 22).

Westerman et al. (2014) and Vial (2019) refer to it as the use of digital technologies in organisations to improve their performance and reach. While Morakanyane et al. (2017) agree with Hess et al. (2016) who define it as an "evolutionary process that leverages digital and technological capabilities to enable business models, operational processes and customer experiences to create value" (p. 22). However, Celis and Ramon (2023), conceive of it in a more holistic way, defining it as:

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The process of adapting and changing the way organisations operate and interact with their customers through the use of digital technologies. This includes automating processes, implementing information systems and adopting new technologies, such as artificial intelligence and the cloud, to improve business efficiency and effectiveness. Digital transformation also includes how companies use digital technologies to create new products and services, and to interact with their customers differently (p. 2).

Digital transformation should be understood as that systemic change or transformation of processes, professional competencies and business models that makes it possible to take advantage of everything that new technologies provide, both to organisations and to all the actors involved. It seeks the use and integration of technology and data so that all members benefit and are able to adapt to any system in the organisation.

Digital Transformation in Education

Currently, the world lives in a constant technological change, where digital transformation is present in all productive sectors: industry, government, society and academia, no one escapes. In this sense, it is important to define it in order to understand how it works, particularly in the field of education.

Almaraz et al. (2017) define the digital transformation of HEIs as the process of technological and organisational transformation driven in these institutions, derived from the development of ICT. However, it is not only the application of technology; it involves all the actors that are part of HEIs, as well as their organisational structures, where they must adapt and adopt a new organisational or institutional model. For its part, the Colombian Quality Assurance System (2021) mentions that digital transformation is an integral and strategic process that contributes to an educational transition, and leads to an educational change for the development of new training scenarios.

In this sense Artuso and Guijt (2020) highlight that the need for this change or process of educational transformation is given by the continuous and accelerated technological development in which we live, linked to technological innovation, hyperconnectivity, changes in work models and the emergence of digital technologies such as the internet of things, augmented reality, virtual reality, blockchain, artificial intelligence and big data, among others.

Some authors such as Iivari et al. (2020), Bryndin (2019), Arango et al. (2018) and Díaz (2022), state that educational digital transformation focuses on the process of strategically, meaningfully and systemically incorporating digital technology in all areas of education, from classrooms to educational management. This integration seeks to improve and enrich the experience of both teaching and learning processes, as well as the optimisation of administrative and management processes in education. Consequently, as part of the context of digital transformation in education, technology becomes an indispensable tool that allows teachers, students, parents and administrators to access a wide variety of digital resources and services.

According to studies by Romero et al. (2023), Viñoles et al. (2023), Valdiviezo et al. (2022) and López et al. (2022), the digital transformation in HEI academic programmes contemplates some aspects in which they coincide: a) personalised learning, b) access to information and resources, c) collaboration and communication, d) assessment and feedback, e) teacher professional development, and d) efficient school administration.

Personalised learning. According to Parody and Isequilla (2022) and Guaña (2023), personalised learning takes into account the characteristics, needs, potential, perceptions and previous knowledge of students; it is therefore proposed as an education focused on inclusive teaching, where students are the main actors in the teaching-learning process. It presents a change in pedagogy, i.e. it modifies the way in which education is delivered, promoting student-centred approaches, active learning and online collaboration.

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Access to Information and Resources. According to Salgado (2023) and Sánchez et al. (2019) information and communication technologies (ICT) have become a key part of the teaching and learning processes in HEIs. As a result, it has led to greater interaction between students and teachers, through more flexible and personalised learning environments, while improving accessibility and inclusion. In this sense, the digitisation of educational materials and access to online information allow for greater availability and updating of resources. Students have access to e-books, digital libraries and repositories, specialised databases, as well as multimedia resources to enrich and strengthen their learning.

Collaboration and Communication. Digital tools facilitate real-time communication between students, teachers and parents. López et al. (2022) point out that they have transformed education, enabling more fluid and enriching communication, regardless of the physical space where students and teachers are located. Hence, online collaboration platforms, discussion forums, videoconferences, as well as social networks enable a more fluid and enriching interaction.

Assessment and feedback. The use of technology allows for the development or application of various ways of assessing student performance (Cabero & Palacios, 2021), whether through online tests, interactive questionnaires or progress monitoring systems, to name a few.

Consequently, teachers can provide immediate feedback to students, helping to facilitate their learning. Where evaluation and impact measurement focuses on the need for new metrics and assessment methods to measure the impact of digital transformation on student learning and performance.

Teacher Professional Development. The digital transformation benefits teachers with the training and updating processes in which they must be immersed. Therefore, they can access online courses, communities of practice and professional development resources to improve their digital and pedagogical competences (Higuera & Rivera, 2022).

It is important to note that digital transformation in education is not simply about replacing paper and pencil with electronic devices. Technology can strengthen and improve educational processes, foster creativity, critical thinking and collaboration, and prepare students to face the challenges of the digital world. Consequently, institutional leadership and teacher training are essential to effectively guide and support digital transformation in HEIs.

Efficient school management. Digital transformation also affects the modernisation of administrative and management processes in educational institutions (Castro, 2023). The use of school management systems, online enrolment platforms and data analysis contribute to improving efficiency, effectiveness and final decision-making. In addition, the need to develop digital skills and promote equity in access to technology. At the same time, it provides opportunities for the personalisation of learning, as well as improving academic efficiency.

Each of these areas where ICTs have become key tools in each one, allows us to understand how a permanent and systemic change has been developed, which has contributed to a digital transformation in HEIs, particularly in each of the actors (students, teachers, administrative staff and parents) that are part of the university community.

Recent studies

Leal and Redon (2022) developed a study on the impact of digital transformation on quality management systems in service sector companies in the city of Cúcuta, with the purpose of evaluating the impact of digital transformation on quality management systems, with a qualitative approach.

The findings show that the companies developed digitalisation and transformation processes, but basic ones; where as a result of the pandemic, they helped to promote digital transformation in the city.

While Renán et al. (2021) focused on digital transformation in the new normal for higher education, where they state that as a result of COVID-19 HEIs have had to rely on technological platforms to continue their educational activities, where digital transformation not only refers to the online courses implemented, but to being able to define an education model that adapts to current needs in favour of the academic quality of the educational programmes offered.

The EDUCAUSE Horizon Report (2022) analyses educational trends in the world, divided into 4 sections: Trends, showing the most relevant lines to be considered in the future (social, technological, economic, environmental and political); Key technologies and practices, which have a significant impact on teaching and learning processes; Scenarios, next 10 years; Implications. Therefore, it highlights the aspects that will accompany these changes: Emerging technologies (disruptive technologies such as artificial intelligence, learning analytics and learning tools); Hybrid learning (hybrid learning models, face-to-face and virtual); Data and analytics (data collection and analysis for decision-making); Post-pandemic changes (impact of the pandemic on educational habits and how they will affect the future of education); Foresight: (foresight of key technologies and practices that will transform higher education in the short term). Based on the above, it enables HEIs to prepare themselves with more tools and more knowledge, but mainly less resistance to technological change.

García et al. (2022) conducted a study to identify the actions and mechanisms that an HEI should consider for its digital transformation. Through a systematic review, based on the PRISMA model from the use of different criteria. The findings show that HEIs should be aware of the degree of digital maturity of students, teachers and the community itself, as well as the state of their infrastructure. The authors also emphasise that HEIs should develop strategic plans to improve the application of digital technology.

López et al. (2022) mention that HEIs must respond to the emerging demands of society. In this sense, their research focused on exploring how digital transformation processes are carried out, based on the perceptions of the members of the educational community. Based on a longitudinal, case study design, the results identified the aspects that contribute to the digital transformation process, such as equipment, teachers and students. In addition to the need for a digital culture as a factor for change, the authors conclude that a greater digital culture accompanied by a cultural transformation model favours educational change.

In the study Towards a digital transformation of the education sector by Cruz et al. (2022), the opportunities and challenges of incorporating technologies as part of the health emergency by COVID-19, appropriation of learning and new pedagogical skills for the future and orderly integration of technologies, as well as the use of available digital resources, are set out. On the one hand, the autonomous performance of students is highlighted. On the other hand, it shows the deep digital and pedagogical divide due to the unequal distribution of resources. The findings of the study highlight that emergency virtualisation enriched the educational process through better communication between students, teachers and institutions. However, the incorporation of ICTs was uneven; digital and pedagogical gaps are evident. It also highlights the need for training and updating of teachers' digital competences for virtual or hybrid scenarios. UNESCO (2023) is developing strategies to address the challenges and opportunities of ICT in education, focusing on an inclusive, rights-based digital transformation of education. In this regard, and in addition to these actions, the UNESCO International Institute for Higher Education in Latin America and the Caribbean (IESALC) is carrying out studies focused particularly on: Digital competences (training of all actors involved to help strengthen them (teachers, students, researchers), construction of instruments to measure the digital maturity of universities); Hybridisation (support to HEIs in the implementation of hybrid models and strategic plans for the improvement of their educational programmes, studies on virtual mobility); Artificial Intelligence (development of manuals regarding the impact of AI on education as well as user guides for AI).

The Inter-American Development Bank (IDB) (2020) states that only those HEIs "capable of anticipating the new times will be able to maintain a position of relevance" (p. 49) in this developed technological world, where the use and exploitation of ICT will make it possible to face the challenges of higher education. 49) in this developing technological world, where the use and exploitation of ICT will make it possible to face the challenges of higher education, highlighting what HEIs should already be incorporating as part of their development plans: adaptive and competence-based learning platforms, education analytics, digital assessment, AI applications, conversational user interfaces, smart campuses, enabling technologies for research enhancement. Implementing them as part of their processes of:

Student recruitment, student experience and satisfaction with teaching-learning processes, experience and performance of researchers in knowledge generation, the administrative relationship with the university, enhancing the campus experience, establishing personalised training programmes for professional re-qualification, platforms for employability enhancement (p. 50).

The above provides a basis for understanding the digital transformation of education, particularly in higher education, highlighting aspects such as its conceptualisation, characterisation, didactic and pedagogical approaches, assessment, leadership, teacher professional development, opportunities and challenges.

Methodology

The purpose of this study is to analyse and understand how higher education institutions are currently addressing digital transformation. The guiding research questions are¿ *In what ways are HEIs undertaking digital transformation in both their academic programmes and academic-administrative processes, what are the effective strategies and practices that HEIs have implemented for digital transformation, what are the challenges and opportunities linked to the adoption of digital technologies in HEIs, and what are the challenges and opportunities that are linked to the adoption of digital technologies in HEIs?*

Therefore, a strategic approach is applied, under systems thinking (Senge, 2012) that allows us to explore as a whole its conception, initiatives, challenges and opportunities related to the adoption of digital technologies in this constantly evolving academic environment. By its nature, the research focuses on the qualitative paradigm, highlighting the characteristics of the educational phenomenon (Hernández-Sampieri, 2018). This was carried out through a systematic review, based on an exhaustive search of scientific literature, as well as an analysis of research and articles with diverse perspectives and updated information to strengthen the study.

The systematic review as a methodological approach, in accordance with the Cochrane Handbook (2011) and *Preferred Reporting Items for Systematic Reviews and Meta-Analyses,* allow recent information to be identified, based on specific criteria, in order to subsequently carry out an analysis of each one of them. It also considers the search for answers to research questions in correlation with the phenomenon under study. According to Hernández et al. (2018) the design of systematic reviews "highlights the use of certain steps in the analysis of data and is based on the procedure of Strauss and Corbin (2007)" (p. 473).

On the one hand, an exhaustive search and analysis of primary sources is carried out, obtaining different perspectives to strengthen the study, taking into account that the purpose is to analyse and understand how higher education institutions are currently dealing with digital transformation. On the other hand, the questions guiding the systematic review of the literature are *In what ways are HEIs undertaking digital transformation in both their academic programmes and their academic-administrative processes, what are the effective strategies and practices that HEIs have implemented for digital transformation, what are the challenges and opportunities linked to the adoption of digital technologies in HEIs, and what are the challenges and opportunities that are linked to the adoption of digital technologies in HEIs?*

For this purpose, a search was carried out in different databases specialised in technology, education and social sciences, such as *ERIC, Scopus, Web of Science*, *Science Direct, Proquest, Redalyc, Scielo, Dialnet,* y *Google Scholar.* Consequently, the scientific literature was reviewed, as well as references of studies related to the topic in order to obtain additional and complementary information.

Thus, the search strategy considered key terms related to digital transformation, educational digital transformation, ICT use in HEIs, such as "information and communication technologies", "higher education", "learning", "virtual platforms", "pedagogical innovation", among others. Filters were used to limit the search to publications in scientific journals, in English or Spanish, in the last 5 years due to the nature of the topic.

Procedure

In order to achieve the purpose and answer the research questions, activities were carried out in the order specified:

1. Identification of key words and the selection of databases according to the subject matter.

2. Inclusion and exclusion criteria for the studies were defined.

3. The period of validity of the sources was determined, from 2018 to 2023.

4. A research protocol was defined for the search of research, dissertations and relevant articles applying the Cochrane Handbook of Systematic Reviews of Interventions, translated by the Iberoamerican Cochrane Centre (2011).

5. A comprehensive search for primary studies on Digital Transformation in Higher Education Institutions was conducted.

6. Around 100 articles were reviewed, of which 50 were selected for full-text review, in databases such as Web of Science, Science Direct, Google Scholar, Proquest, Redalyc, Scielo, Dialnet, among others.

7. Following a detailed review, only 15 articles were selected for inclusion in this article.

8. The selected articles cover different topics related to ICT in higher education, digital transformation, digital educational transformation, including the impact of ICT on learning, educational quality and pedagogical innovation, as well as the implementation of virtual platforms and e-learning programmes. Various methodologies were used in the studies, such as surveys, interviews, documentary analysis, case studies, among others.

9. Instruments designed by the authors were defined based on templates from the Cochrane Handbook (2011): Checklists for Assessing and Selecting Sources, Matrix for Organising Information, Description Matrix for Assessing and Selecting Primary Sources, Summary Content Sheets, Checklist for Filtering Experts.

Results

The findings presented below are aligned to the research questions.

How are HEIs implementing digital transformation both in their academic programmes and in their academic-administrative processes?

The results highlight that digital transformation has contributed significantly to the improvement of the quality of higher education academic programmes. There has been a clear improvement in the student learning experience, which has become more interactive and personalised, focusing on quality of teaching and learning, student satisfaction, classroom engagement, digital skills enhancement, faculty perceptions, learning outcomes, process quality and user satisfaction, however it has not been inclusive for all stakeholders in the institution.

What are the effective strategies and practices that HEIs have implemented for their DL?

Strategies for successful implementation of digital transformation were identified, including effective teacher training, strategic alignment of technology with educational goals, as well as the promotion of interdisciplinary communication and collaboration.

What are the challenges and opportunities linked to the adoption of digital technologies in HEIs?

The results show the need to address the ethical and privacy challenges that accompany digital transformation. Concerns about the collection and use of student data are evident in the studies, and solutions such as transparent privacy policies as well as the promotion of ethics in educational research are proposed.

Significant variability in the adoption of digital transformation in different geographical regions and institutional contexts was also detected. This finding emphasises the importance of tailoring digital transformation strategies to the local needs and characteristics of each institution. Digital transformation has had a positive impact on student participation and engagement in the educational process. Strategies such as the use of interactive platforms and gamification approaches are shown to be effective in fostering greater student participation and deeper engagement with the content.

The findings reflect a clearer picture of how digital transformation has influenced higher education, highlighting both its benefits and challenges. Furthermore, it underlines the importance of adapting digital transformation strategies to address contextual and geographical differences, while prioritising the enhancement of students' educational experience.

Discussion

This study focused on distinguishing, analysing and understanding how HEIs are realising digital transformation in both their academic programmes and their academic-administrative processes. Therefore, first, the need to tailor digital transformation strategies to meet the unique needs of each institution is identified. Although successful strategies were identified, it is clear that effective implementation requires flexibility and adjustment to the individual circumstances of each university.

This is confirmed by Romero et al. (2023) and Viñoles et al. (2023), who argue that digital transformation in HEI academic programmes should consider strategies focused on personalised learning, learning communities, collaboration and communication, learning assessment, and teacher professional competences, through digital inclusion as part of the whole system. In such a way that digital transformation strategies are adapted to the specific needs and characteristics of each institution, as well as to its context.

Second. Findings related to challenges and opportunities lead to the implementation of clearer policies and the creation of ethics committees to oversee the collection and use of student and teacher data due to the risks currently being taken. As Galan-Muros & Bosen (2023) argue, there are ethical and privacy concerns regarding data collection, as well as the use of artificial intelligence; hence these are crucial issues for higher education to address.

Furthermore, the Ibero-American Business Council (2021) emphasises the importance of:

The transversality of coherent public policies and the training of human capital skills. Not only must new generations be educated for the future, but current workers must also undergo a process of reconversion to make efficient use of connectivity (p. 78).

Thus, the regulations to be defined should facilitate the processes of digital transformation of education in institutions and not hinder it. Universities should also adapt their digital transformation strategies according to geographical and contextual differences, recognising that what works in one place may not be effective in another. This is in line with Salgado (2023) and Sánchez et al. (2019), where ICT are indispensable tools in teaching and learning processes for academic programmes. This allows for greater interaction between students and teachers, through virtual learning environments and learning communities, which are more flexible and personalised, favouring accessibility and inclusion.

Therefore, it is evident that HEIs are unaware of the degree of digital maturity of their stakeholders (students, teachers and administrators) as well as the current state of their infrastructure. Hence, as mentioned by Salgado (2023) and Sánchez et al. (2019), even when ICT have favoured accessibility and inclusion. On the one hand, it is necessary to carry out evaluations focused on the impact that educational materials and access to online information have on students' learning processes. On the other hand, whether the infrastructure available to the academic programme is sufficient to actually carry out actions that contribute to the permanent and systematic digital transformation that is currently required.

Furthermore, the studies reveal that most HEIs do not have strategic plans to improve the use of digital technology, both at methodological and instrumental level, thus facilitating digital transformation at the level of infrastructure, digital competences of both teachers and students, favouring the digital inclusion of the entire system, which as mentioned by García et al. (2022) the benefit lies in improving educational quality, as well as in the application of digital technology.

For all of the above reasons, it should be noted that the digital transformation of education, through the use of emerging technologies, seeks the digital wellbeing of higher education students. In this way, it reduces the gaps in the different digital ecosystems that HEIs are experiencing within themselves. Considering that we are in a process of permanent and systematic educational digital construction, where all the actors involved must make it their own, take ownership of it.

Conclusions

The digital transformation has had a positive impact on the quality of teaching and learning in higher education institutions. Greater interaction and personalisation of learning has been observed, which has contributed to an improved student experience. Effective measurement of this impact involves assessing qualitative indicators, such as student satisfaction, classroom engagement and digital skills enhancement, rather than relying solely on traditional quantitative metrics.

Several successful strategies and best practices for implementing emerging technologies in higher education have been identified. These include effective faculty training, strategic alignment of technology with learning objectives, and promotion of interdisciplinary collaboration. These strategies are critical to ensure effective and successful implementation.

Challenges are significant concerns in the process of digital transformation in higher education. These include the collection and use of student data, as well as the protection of student privacy. Appropriate solutions involve implementing transparent privacy policies, promoting ethics in educational research and adopting effective data security measures.

The adoption of digital transformation varies significantly in different geographical regions and institutional contexts. Contextual factors, such as the size of the institution, geographical location and available resources, have a substantial impact on how universities approach digital transformation. Strategies must be adaptable and consider the specific needs of each context. In short, it is essential for HEIs to have strategic plans focused on the digital transformation of their academic programmes, which has a direct impact on their educational quality and favours the digital inclusion of the whole system.

Implications of the study

The findings of the study on digital transformation in higher education institutions have important implications for educational institutions. These can guide strategic and operational decision making in managing digital transformation, such as:

1. *Strategy development*. Formulation of more robust digital transformation strategies tailored to the specific needs and characteristics of the institution. HEIs should identify best practices and strategies that fit their context.

2. *Teacher training*. Effective strategy, where HEIs should prioritise the training and professional development of teaching staff to ensure successful implementation of technology in the classroom.

3. Ethics and privacy. Challenges and opportunities for HEIs should lead to the implementation of clearer policies and the creation of ethics committees to oversee the collection and use of student and teacher data.

4. *Adaptation to contexts*. HEIs should adapt their digital transformation strategies according to geographical and cultural differences.

5. *Investment in technology*. HEIs should pay special attention to making decisions on the technological investment required for their academic programmes. Where they adopt emerging technologies that are effective in improving the quality of education.

6. *Continuous measurement and evaluation*. Effective measurement of the impact of digital transformation should lead to an emphasis on continuous data collection and analysis to assess progress and make strategic adjustments.

7. *Strategic partnerships*. HEIs should enter into strategic partnerships with technology companies or other educational institutions to access additional resources and expertise in the field of digital transformation.

8. *Evaluation of results*. HEIs should focus on the assessment of student learning outcomes, using specific metrics related to the impact of digital transformation on academic achievement.

9. *Organisational change management*. Digital transformation requires significant changes in the institution's culture and practices (processes, technologies, people).

In summary, the implications of this study on digital transformation in higher education can help HEIs to make informed decisions, adopt effective strategies, as well as improve the quality of teaching and learning through technology. These implications can guide the future direction of the institution in an ever-changing educational environment.

Recommendations for future studies

Based on the needs, experiences, and limitations of this study, research is recommended focusing on: Key technologies for educational digital transformation, Integration of Technology in the educational process, Pedagogical innovation and teaching models, Teacher professional development in the digital context, Design of an educational digital transformation plan, Long-term impact of digital transformation on the quality of teaching and learning, Effectiveness of digital transformation strategies in diverse educational contexts, to name a few. This will help to complement and deepen the knowledge of this constantly evolving field and validate the findings obtained in the literature review. It also emphasises the need for more specific research that explores the particularities of each higher education institution.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Authors' Contribution

The contribution of each researcher in each of the points developed in this research, was defined based on:

Rivera-Gutiérrez, Erika: Development of the study centred on the subject being addressed, defining the problem statement, context of the study, purpose, review of scientific literature, methodological design, implementation, results and discussion.

Higuera-Zimbrón, Alejandro: Review of scientific literature, implementation of the methodological design and discussion.

Argüello, Georgina: Data collection and analysis.

Availability of data and materials

The data for this research are available according to the sources consulted.

ECORFAN Journal-Spain

Article

Funding

Abbreviations

IDB. Inter-American Development Bank.

HEI. Institutions of Higher Education.

IESALC. Higher Education in Latin America and the Caribbean

OECD. Development Centre of the Organisation for Economic Co-operation and Development.

SMACiT. Social, Mobile, Analytics, Cloud Computing & Internet of Things.

TD. Digital Transformation

ICT. Information and Communication Technologies.

UNESCO. United Nations Educational, Scientific and Cultural Organisation.

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Integration of architecture and communication: a transversal learning methodology empowered by artificial intelligence tools

Integración de arquitectura y comunicación: una metodología de aprendizaje transversal potenciada por herramientas de inteligencia artificial

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## Abstract

With the growing implementation of Artificial Intelligence (AI) in the architectural field, significant challenges arise in education with ethical and social connotations. In the context of Architecture and Communication degrees, AI emerges as an essential tool, especially in the initial stages of architectural design in exploring ideas and conceptualizing projects. This article addresses the complexity inherent in using AI in architecture, highlighting its fundamental contribution to improving visual representation through textual algorithms, and analyzes the relevance of communication as a scientific discipline. In this context, communication in architecture is directed towards advertising and the effective transmission of messages. The article presents a methodology focused on detecting didactic errors among architecture and communication students, thanks to multidisciplinary collaboration. In conclusion, it is highlighted that the appropriate use of AI can boost the generation of creative ideas, allowing students to direct them and complement them in technical aspects. This study highlights the importance of effectively integrating AI into academic training, highlighting its benefits in improving creativity and precision in architectural communication.

Resumen

Frente a la creciente implementación de la Inteligencia Artificial (IA) en el ámbito arquitectónico, surgen desafíos significativos en la educación con connotaciones éticas y sociales. En el contexto de las licenciaturas en Arquitectura y Comunicación, el uso de IA emerge como una herramienta esencial, especialmente en las etapas iniciales del diseño arquitectónico en la exploración de ideas y la conceptualización de proyectos. Este artículo aborda la complejidad inherente al uso de IA en arquitectura, destacando su contribución fundamental a la mejora de la representación visual mediante algoritmos textuales y analiza la relevancia de la comunicación como disciplina científica. En este contexto, la comunicación en arquitectura se dirige hacia la publicidad y la transmisión efectiva de mensajes. El artículo introduce una metodología centrada en la detección de errores didácticos entre estudiantes de arquitectura y comunicación, gracias a la colaboración multidisciplinaria. En conclusión, se subraya que el uso apropiado de IA tiene el potencial de impulsar la generación de ideas creativas, permitiendo a los alumnos dirigirlas y complementarlas en aspectos técnicos. Este estudio destaca la importancia de integrar de manera efectiva IA en la formación académica, resaltando sus beneficios en la mejora de la creatividad y la precisión en la comunicación arquitectónica.
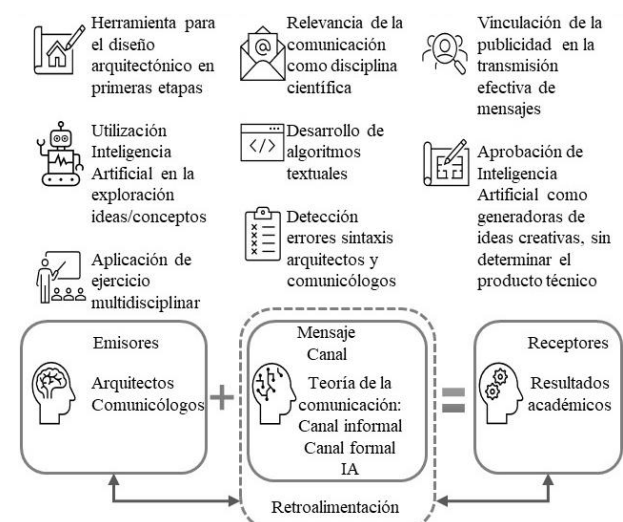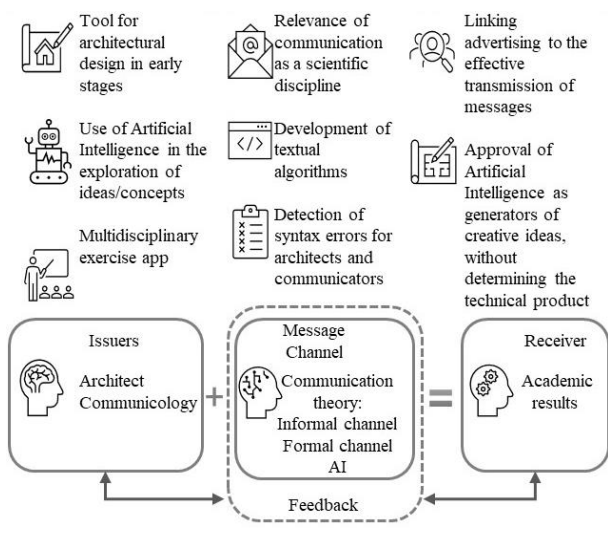
Architecture, Didactic communication, Artificial intelligence

Arquitectura, Comunicación didáctica, Inteligencia artificial

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Introduction

The inception of a requirement marks the beginning of any communication or architectural project, signifying the opportunity to create an innovative and highly functional solution. The realization of an architectural endeavour, spanning from its initial phase to remodelling processes, requires methodical steps that encompass the trinomial criteria: functional, aesthetic, and structural, with the current inclusion of the environmental aspect. In the preliminary stages, it is imperative to delineate the project's nature and initiate the analytical phase, involving considerations of physical context conditions, program determination, and cultural and social factors.

This is where the generation of ideas begins, and the concept takes form, rooted in technique and geometry. These ideas find expression in architecture through concepts grounded in the theory of integrating elements and design principles. The former includes point-line, direction, shape, size-scale, colour and texture (Pastor, Martin, & Pintado, 2018), while the latter comprises emphasis, balance, equilibrium, rhythm, movement, proportion, scale, unity, harmony, contrast and space (Ching, 2015). These elements collectively shape the graphic representation of the design and serve as the guiding concept of the project. The final stage involves the actualization of the idea through the preparation of technical documents that mirror the intellectual work of the initial two stages.

Throughout the entire process, linguistics, which concerns the relationship between meaning and signifier, plays an essential role as a guide for the development of proposals. Before the emergence of modernism, projects were governed by a set of rules, codes, and lexicon, wherein the built work ensured its permanence through dialogue. Subsequently, modernism opened the conversation to new languages, determined by the personal temporal context of the architect and his limits of openness to the outside world, eventually reaching the digital age (Muñoz-Cosme, 2018).

Carpo (2017) distinguishes between two digital eras. The first, known as the era of mass customization, characterized by the use of digital tools to create unique designs through parametric and algorithmic processes. This period encompasses the emergence of parametric design and digital manufacturing technologies, enabling architects to produce complex, non-standardized architectural forms. In contrast, the second digital age represents a shift toward a more standardized and automated approach to architectural design. This stage is highlighted by the increasing influence of artificial intelligence (AI) and machine learning in the architectural design process. Carpo argues that the second digital era is distinguished by the utilization of AI to generate architectural designs, leading to a transformation in the conception and development of architectural forms by architects (Al-Azzawi & Al-Majidi, 2021).

At this juncture, the use of digital tools alters the perception within the methodology of stages two and three. According to Champitaz (2020), engaging with the client constitutes the social aspect of the design, a linguistic discourse that must be imbued with empathy and assertive signifiers of the preceding stages. This type of communication cannot be achieved using artificial intelligence (AI) tools.

However, using artificial intelligence as a tool for architectural design addresses several critical problems and challenges in the disciplinary field. AI aids in generating architectural intentions and forms, supporting academic and theoretical models, fostering technological innovation, and improving the efficiency of the architectural design industry (Li, Wu, Xing, & Wang, 2023). It offers the potential to inspire and enhance architectural design but must be used ethically and responsibly to avoid negative impacts on human creativity and design ethics (Hegazy & Saleh, 2023). Furthermore, AI can assist in developing a virtual environment for conceptual design in architecture, providing a platform for architects to experiment and visualize design concepts (Cudzik & Radziszewski, 2018). As well as creating intelligent design agents by providing quantitative ways to measure customer needs and preferences and offering a mathematical framework for making design decisions (Sherif, Asadi, & Karan, 2018).

In the present study, the results of an academic exercise that integrates three types of channels in the dialogue are presented: User (informal communication)-Architect, Architect-(formal communication)-IA and User/collaborator-(formal communication)-Architect. This integration aims to gather student assessments and identify potential enhancements in the teaching model while responsibly and ethically promoting the use of AI tools in learning strategies, without compromising skills such as the ability to efficiently conceptualize space in three dimensions. The primary contribution lies in the integration of multidisciplinary teams in project development, optimizing execution times, and ensuring effective communication with users through the use of AI tools.

The science of communication and architecture

To understand the interaction between communication sciences and architectural design, is essential to delve into its historical development. The emergence of communication sciences as a discipline date back to the early 20th century, driven by advances in technology and media studies. At the same time, architectural design evolved in response to social and cultural changes. The two disciplines intersected as architecture increasingly incorporated visual and spatial communication techniques to convey meaning and create liveable experiences.
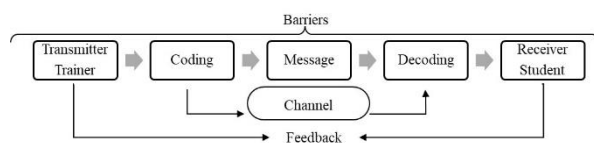
Box 1

Figure 1

Outline of the communication process
Source: (Berlo, 1987)

In its basic form, Communication Theory investigates and studies the ability of certain living beings to establish relationships with others through the exchange of information. According to Otero (2019), the use of the word "communication" depends on the context, for example, a fact (gesture, conversation, use of technological resources, media programming), engineering (advertising, propaganda, campaigns) and the theory (models, hypotheses, intellectual products). Communication as a science is responsible for studying the communicative processes, the exchange of information between two or more participants or users in order to transmit data, it uses elements such as: sender, receiver, message, code, channel, and context (Fig. 1).

In changing information, ideas, and feelings, it is essential to have standard codes for the sender and the receiver. At this moment, semiotics, the study of the sign and its meaning, enters the scene. Architecture and communication, in their theoretical form, have been linked to concepts such as semiotics, semantics, denotation, and connotation. Semiotics in architecture analyze spatial configurations, shapes, materials, light and colours, and their meanings, evoking specific sensations and responses in users (Barthes, 1991; Venturi, Stierli, & Brownlee, 1977; Eco, 1979). Semantics, closely related to the previous concept, allows for consideration of the context in which these signs and symbols are interpreted to ensure that users effectively understand the intended meanings (Norberg-Schulz, 2019; Jencks C. , 1978), the synergy between architecture and communication seeks to create designs that resonate on a conscious and subconscious level with users.

Denotation is the primary function, object, or essential action, which in architectural language translates as a clear and direct communication of purpose and utility (Groat & Wang, 2013; Boonyanan, 2018). On the other hand, connotation refers to the subjective, associative, and cultural values that individuals attribute and add to said object or action (Jencks C. , 1997; Pallasmaa, 2012, pág. 33). These are some of the basic concepts of communication theory that interact with Architecture.

However, conceived as a science, communication includes methodologies to conduct user research, analyze their perception, and develop narratives that inform architectural decision-making using AI tools, such as corporate identity. The corporate identity consisted of associating the needs of the students in a community space for coexistence and food with the identity of the public university faculty. The communication students developed this concept. As a result, a document was delivered to the architecture students to carry out an exercise intended for a social space in the Faculty of Communication Sciences of the Universidad Veracruzana, Veracruz Region.

The document called Corporate Identity was detailed and offered information on the company involved, which is Veracruz University and the faculty cafeteria, presenting a specific project that determined the conceptual, functional stages, representation, communication, and analysis of results with AI tools. that facilitated communication and exchange of ideas at all stages and determined objectives; Within the creative area it allowed the development of the design concept, its communication, marketing, and advertising (Busch, Sander Jensen, & Barros, 2023). The importance of a brand report (Brief) consists of having reference elements: description, background, and context; operational elements: objectives, measurable strategies, and schedule; and determining elements: restrictions, budgets, deliverables, and times.

Another instrument is the brand management document (Branding), to create, both at the creative level with the diagnosis, the reference points, the individuals or groups of interest and impact, and the descriptive map of the customer experience towards the product (Benchmarking, Stakeholders, Customer journey map, respectively); until achieving positioning in the consumer's psyche (focused on marketing, Target). As Philip Kotler, father of marketing, defines it: *"Branding is a communication exercise to define what you are since each company wants to be in the minds of its consumers"* (Endor, 2023).

Finally, Corporate Identity presents the projection of the company, including its logo, colors, typography, vision, mission, values, and, in general, the image. This theory mentions that *"It is the image management process, the fundamental variables are: identity, communication, image, and feedback. The reality of the corporation of its unique and individual personality differentiates it from other companies"* (García, 2021).

Computing in the architecture learning process

Computer science in the Architecture profession has created excellent digital tools for design and construction, and its effect on practice and education has been manifest for four decades (Andía, 2022); speaking only of design, there are currently countless software, such as AutoCAD, 3D StudioMax, Sketch-UP, V-Ray, Revit AutoDesk, and ArchiCAD, which are beginning to experiment with AI, for the moment, they are highly used in the professional field of architecture and construction as means of representation, communication, visualization and realization of deliverables for the construction of a project, regardless of what other software supports in the decision of technical, structural, installations, bioclimatic, costs and energy efficiency aspects.

It should be understood that the difference between a computer program and software is that a machine does not analyze; it simply performs the actions for which it has been programmed. Therefore, it responds logically to orders: If this happens, do it. On the other hand, artificial intelligence (AI) also receives orders; however, after the instructions, its objective is to collect data in big data and provide solutions (Teknei, 2023). Analyzing the origin of AI, Turing (2007) defines it as the ability to ensure that a machine has human-level performance in cognitive tasks without being detected by humans. For this, learning as an objective becomes fundamental (Machine Learning), dividing it into automatic and deep. The first is classified as Supervised, Unsupervised, and Reinforcement Learning and the second is based on using Artificial Neural Networks, that is, data interaction on an autonomous basis (Díaz-Ramirez, 2021).

Currently, these tools replace the manual skills of technical representation in the profession; however, the use of these In academic life may have another meaning if they seek a different purpose from mere visual representation (Rocker, 2010). Therefore, educational programs continue to encourage the student to complete their basic skills and abilities of manual graphic communication to express their ideas and obtain sufficient maturity to create their digital content and designs in the physical-cultural context of the project, that is, with meaning and without plagiarism.

Some research (Gómez, 2011; Bohórquez, Montañez, & Sánchez, 2020; Guzmán & Caderon, 2020; Vera, 2022), established the advantages of using digital tools in architecture education, which, in addition to being excellent means of representation in learning they support logical-methodological thinking, the analysis of design and research processes, and allow rapid feedback and interaction between teachers and students, the researchers conclude that it will enable improving the analysis-generation-evaluation of the development of a project, widely recommending the interaction and promotion of the combination between analog, digital models and physical models (models) at different scales. Başarir (2022) suggests that integrating AI into the architectural design curriculum is beneficial in increasing students' awareness of all areas of architectural design in the form of input, process, and output. Likewise, as Ocegueda et al. (2022), New technologies and tools are being integrated into education as part of the methodology, without this being separate from technological development. Therefore, it is essential for the teacher, although not necessarily to master all the tools, to have general knowledge and, above all, an openness to incorporate ICT tools both in the teaching of the class and in promoting their use among the students.

The revolution in digital tools has recently incorporated the use of Artificial Generative Intelligence (IAG). In less than a decade, its influence on architectural design has begun to be noticed. AGI is an aspect of artificial intelligence that focuses on generating completely new data or content from existing ones using machine learning algorithms and data from datasets (Mantengna, 2020).

Regarding the plagiarism of intangible assets such as artistic and literary creations, it is essential to highlight that security and transparency in copyright management are being supervised and protected through new tools such as (Kuznetsov, Sernani, Romeo, Frontoni, & Mancini, 2024). These tools seek to establish new regulations, which is essential for communicating with students.

Regarding its application, specialists indicate that the use of this technology in architectural design is based on the user's ability to provide commands or instructions, known as "prompts," of text that AI programs can recognize (Beyan & Rossy, 2023). It is at this point that semiotics becomes relevant again. Some examples of GAI include Bluewillow, Craiyon, Dalle-2, DreamStudio, Firefly, Hotpot - AI Art Maker, Midjourney, Nightcafe, and StableDiffusion Web (Basteros, 2023).

It must be considered for use IAG; there is an appropriate programming lexicon, which, although at the beginning they may be ordered based on their criteria, later on, the user, if they wish to specialize, must analyze guides to determine the appropriate prompts, negative prompt, style, upload image and setting (prompt strength, noise, seed, model) that recreate the product suitable to your needs. The manuals or tutorials offered by the different AI services are free (Stability.ai, 2022; Craiyon, 2023; Stable, 2023). However, the new generation of ChatGTP 4, according to Törnberg (2023), implements a new Large Language Model (LLM), which allows correctly correcting messages that require reasoning based on contextual knowledge and inferences about the author's intentions, traditionally seen as unique human abilities. With this, it offers that, through a simple command, the appropriate prompts are generated for generating images and videos in IAG, avoiding noise errors, barriers, and channels and improving the semiotics between both (architect [user] - IAG). New lines of research propose task data schemas to develop a new language, such as in the interaction between design and model manufacturing, called co-design (Skoury, y otros, 2024).

Academic exercise proposal for architecture students

The academic exercise is aimed at students in the second semester of the Architecture Degree; its objective is the interior design of a social and community space, semi-open, contained between two buildings, which serves as a cafeteria in a university educational space. For students to interact with users and space, the actual space in this exercise is located in the Faculty of Communication Sciences, on the Mocambo Campus of the Universidad Veracruzana, Veracruz Region. The city and Port of Veracruz have a tropical climate, with rain in summer, classified as Aw2 (warm and humid climate greater than 55.3%) by Köppen-Geiger. The average annual temperature is 28 °C, with maximum and minimum values of 35 and 20 °C; the average, maximum, and minimum RH are 80%, 89%, and 67%, respectively, and average annual precipitation of 1516 mm/year, with maximum monthly values of 360 mm in July, also presents an increase in its temperature per decade of 0.59 °C (Grajeda-Rosado, y otros, 2022) (Fig. 2).

Box 2

Figure 2

Process Photographs of the exterior space to be remodeled at the Faculty of Communication Sciences, at the Universidad Veracruzana

Source: Own elaboration

Methodology

A qualitative research approach was used (Tamayo, 2007) since the collection of non-numerical data was previously sought to describe and refine the current phenomenological situation. According to Hernández et al. (2014), the study corresponds to an exploratory approach because, although there is an established problem, it is not clearly defined; that is, the study begins to understand it without providing conclusive results and, finally, it is descriptive because it analyzes the characteristics of the phenomenon and allows us to define, classify, summarize and determine a method to address the problem.

In the first part, the wording of the exercise was: Remodelling of the cafeteria space of the Faculty of Communications where students carry out actions such as having breakfast, homework, and recreational activities, creating a concept of identity in the users, with the conditions of not subdividing the space, use of university institutional colors, and develop proposals for improvement in visual and thermal comfort. Therefore, the expected final result has as its rubric that the teams generate an innovative and unique proposal, qualifying that they consider aspects of functionality and global image of the space with its environment, creativity, coherence in its textual and visual discourse, as well as the introduction of basic bioclimatic techniques, which will be valued, not only by the subject teachers but by the authorities of the educational establishment and the users themselves.

The proposed methodology for the academic activity carried out by first-grade students is divided into four stages.

- The first stage has two types of communication interaction: informal and formal. The first is direct contact with the users of the space and internal collaboration between communication scientists and architects, who must analyze and understand their collective imagination of the space. This communication is carried out with colloquial language and has no restrictions. The product expected by future architects is the guiding idea, with graphic representations using manual techniques.

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- The second stage provides formal communication to the architect through a Brief, Branding, and Corporate Identity document prepared by the Communication degree students, which refines the architectural project proposal.

- Subsequently, knowing all this information, with a product prepared with traditional teaching-learning methods, the teams were encouraged to use AI, using primary technical language, to obtain new images and design suggestions. The expected product is graphical representations using digital techniques with IAG.

- Finally, a physical model, a scale model, was requested, which allowed us to perfectly understand the three-dimensional space and the team's final proposal.

Results

The results varied significantly, heavily influenced by the students' individual styles and backgrounds. Nonetheless, certain consistent elements, such as the utilization of green and blue, align with the university's institutional image. Another notable aspect of the project was the necessity to convey "theories of communication," a concept strongly emphasized by both users and collaborators due to the proposals being deeply embedded within the faculty that teaches said program.

Informal communication and graphic representation with manual technique

The outcomes exhibited considerable diversity, strongly influenced by each student's unique personal style and individual background. However, certain constants, such as the use of green and blue colors, are integral to the university's institutional image. Another distinguishing feature of the project involved the imperative to convey theories of communication, a concept highly sought after by users and collaborators, as the proposals are deeply rooted within the faculty that instructs the aforementioned program (Fig. 3).

Box 3

Figure 3

Products of the first stage of Architecture students, Universidad Veracruzana

Source: Own elaboration

Formal communication (Communication techniques)

The next step is formal communication, which becomes the concretization of the idea. This part of the information is the Brief generated by communication students. This document complements the information of the architecture student and brings him closer to the possibility of a sales project, seen from a marketing point of view.

a) The information provided consists of four points: a) diagnosis, emphasizing where the project is culturally immersed, such as the student environment, beliefs, and values; concretizing the governing concept or idea (Fig. 4)

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b) Benchmarking, locating the specific dimension of the product or service, where the emotional benefits of the public are questioned, in this case, a survey was carried out whose results demonstrated the needs of users to express themselves openly, avoid stress and seek entertainment; without leaving the functional ones that are comfort, tranquility and light.

c) Stakeholders, who determined the interested parties and personalities that affect decision making, such as suppliers, clients, collaborators, administrators, and directors; and

d) Customer journey map, which locates the space concerning its exterior, establishing the user's contact points with the brand, detecting weaknesses and improving efficiency and user experience (Fig. 5).
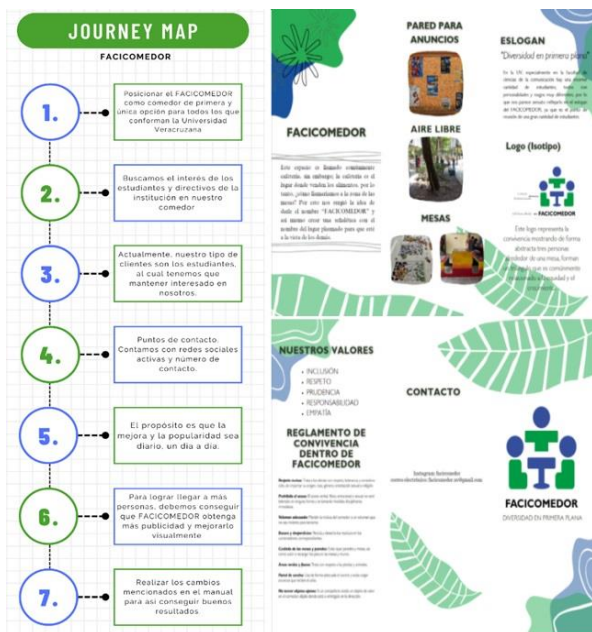
Box 4

Figure 4

Costumer Journey Map

Source: Own elaboration

Conceptualization with IAG

The previous results show a firm intention to reflect the user's needs and express the personality of the future architect; however, AI allows for generating a new vision for the student. To achieve the desired results, the IAGs introduced different and equal prompts, covering negative, positive, short and long description commands, as well as creation by areas or walls.

Box 5

Figure 5

Surveys and integrative project of the activities of the students of the Faculty of Communication Sciences of the Universidad Veracruzana

Source: Own elaboration

The results vary and depend not only on the order given but also on the type of artificial intelligence used; however, the results between Dream Studio and Blue Willow are similar. The "prompt" command used on the different IAG web pages generally mentions that the space is semi-open, with lighting, and in some cases, you are asked to add communication symbols. Below are the results obtained according to a specific program used and different applications of IAG.

IAG Dream Studio (Fig. 6).

Prompt utilized: Generate an architectural render of a space between two buildings with a school cafeteria. The buildings should have a modern design, allowing for seamless integration. Inside, the cafeteria features efficiently organized benches with built-in electrical connections for charging devices. Include green areas, a designated space for important announcements, strategically placed wall fans, and appropriate lighting.
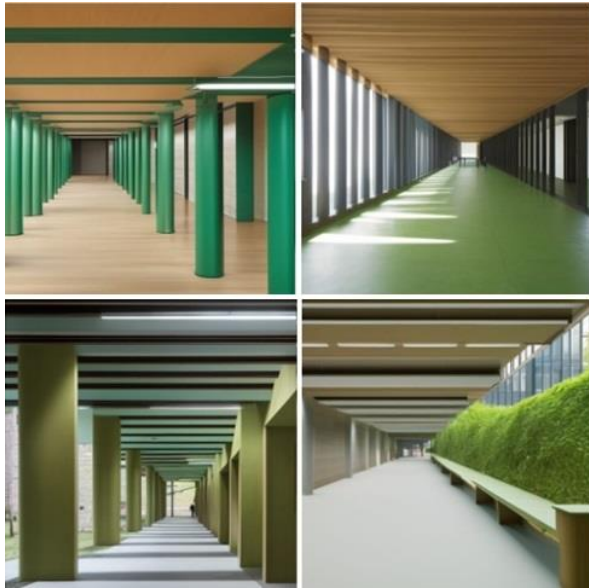
Box 6

Figure 6

Images obtained from IAG Model SDXL Beta

Source: Own elaboration

IAG Night Cafe (Fig. 7).

Prompt utilized: An open space between two buildings, with a hallway extending along it with green areas, 6 wooden tables in the central part, benches around the green area. The walls of the hallway are divided into 8 parts by columns with a mural representing communication career, using a green and blue line of 1-meter thickness.
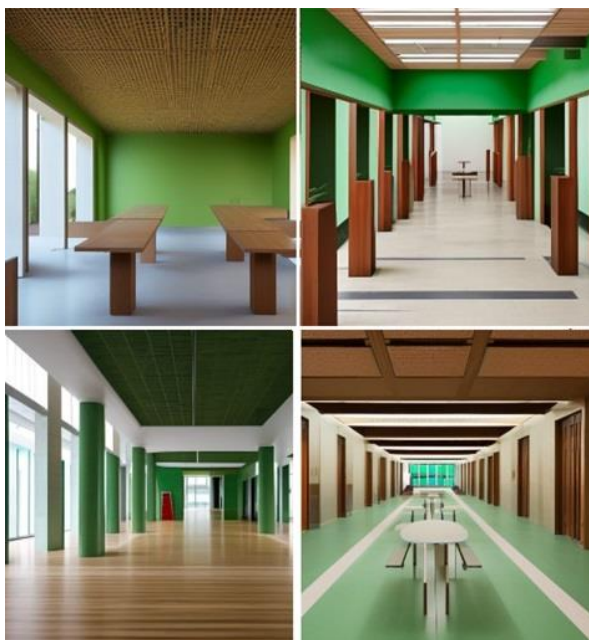
Box 7

Figure 7

Images obtained from IAG Night Cafe

Source: Own elaboration

IAG Model SDXL Beta (Fig. 8).

Prompt utilized: An open space between two buildings of 26 meters long and 7.8 meters wide, with a hallway extending along it with green areas, 6 wooden tables in the central part, benches around the green area. The walls of the hallway are divided into 8 parts by columns with a mural representing communication career.
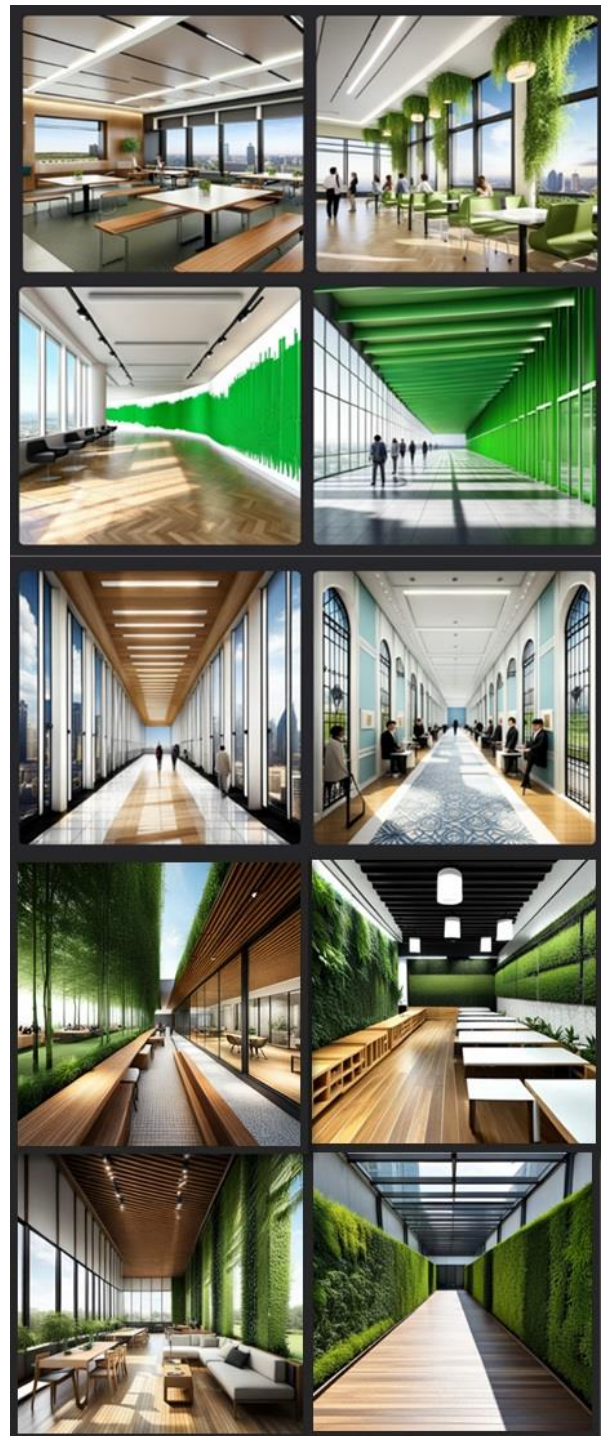
Box 8

Figure 8

Images obtained from IAG Dream Studio

Source: Own elaboration

Article

IAG Craiyon (Fig. 9).

Prompt utilized: School hallway 7 meters wide and 26 meters long, with a continuous green and blue line painted on the walls and forming symbols that represent the communication degree. A long school hallway decorated with bachelor's symbols. The corridor is closed, the green area is simply green, with poor proportions and inadequate lighting, the corridor is located within a building.
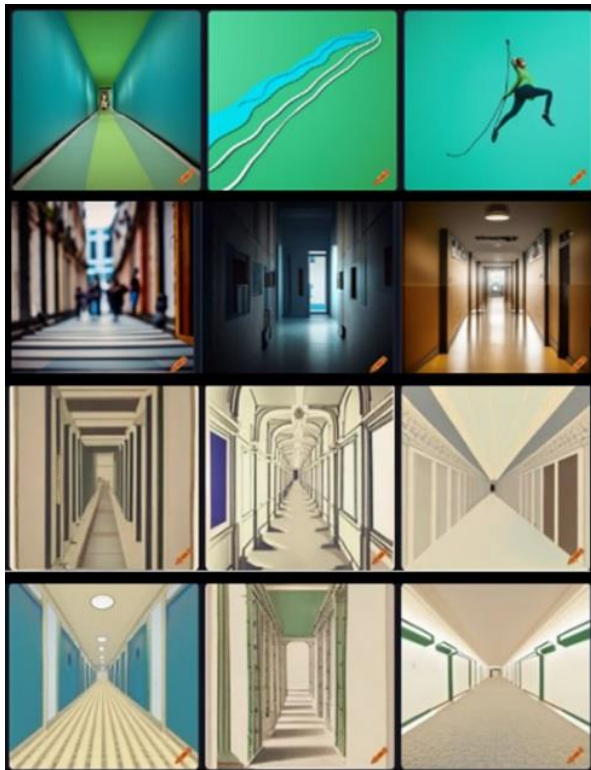
Box 9

Figure 9
Images obtained from IAG Craiyon
Source: Own elaboration

IAG Dall – E (Fig. 10)

Prompt used: School classrooms with a 7-meter hallway with planters, 7-meter-wide school hallway, with green areas at the beginning and end of the hallway.

Prompt used: School hallway 7 meters wide and 26 meters long with murals on the walls representing the degree in communication through symbols and curved lines.
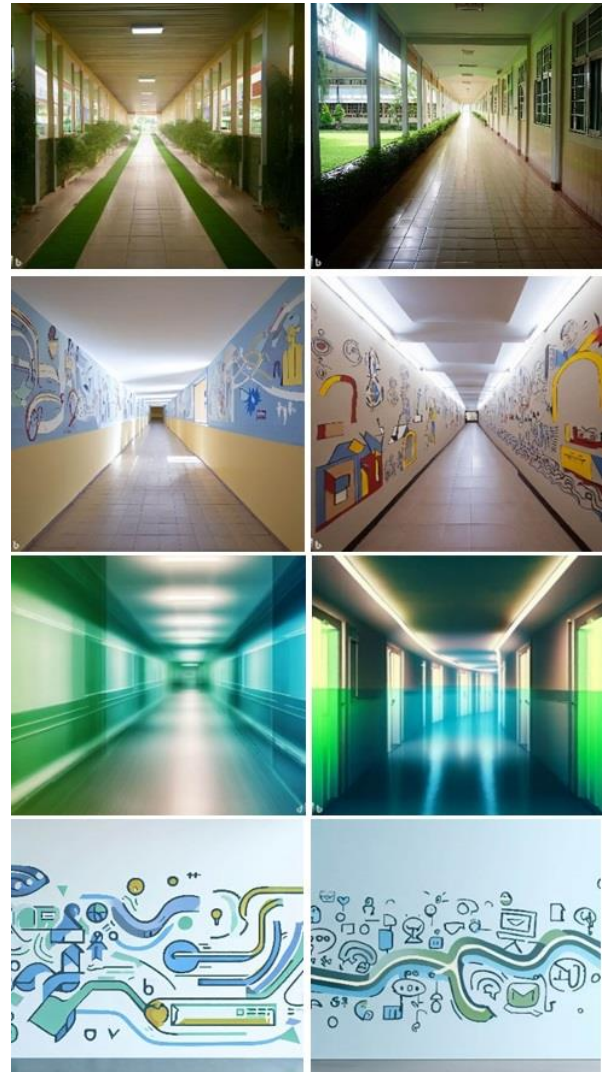
Box 10

Figure 10
Images obtained from IAG Dall-E
Source: Own elaboration

IAG Stable Diffusion Web (Fig. 11)

Prompt utilized: An open space between two buildings of 26 meters long and 7.8 meters wide with a hallway extending along it with green areas located at the beginning and end of the hallway. Benches are placed around the green area to delimit it, leaving a small space for people to pass and trash cans on each side. The walls of the hallway are divided into 8 parts by columns, they are ivory colored with a mural that represents the communication career, using a single line of 1 meter thickness, green and blue in color that extends throughout the wall, and which forms abstract symbols such as a camera, a hearing aid, and a microphone.

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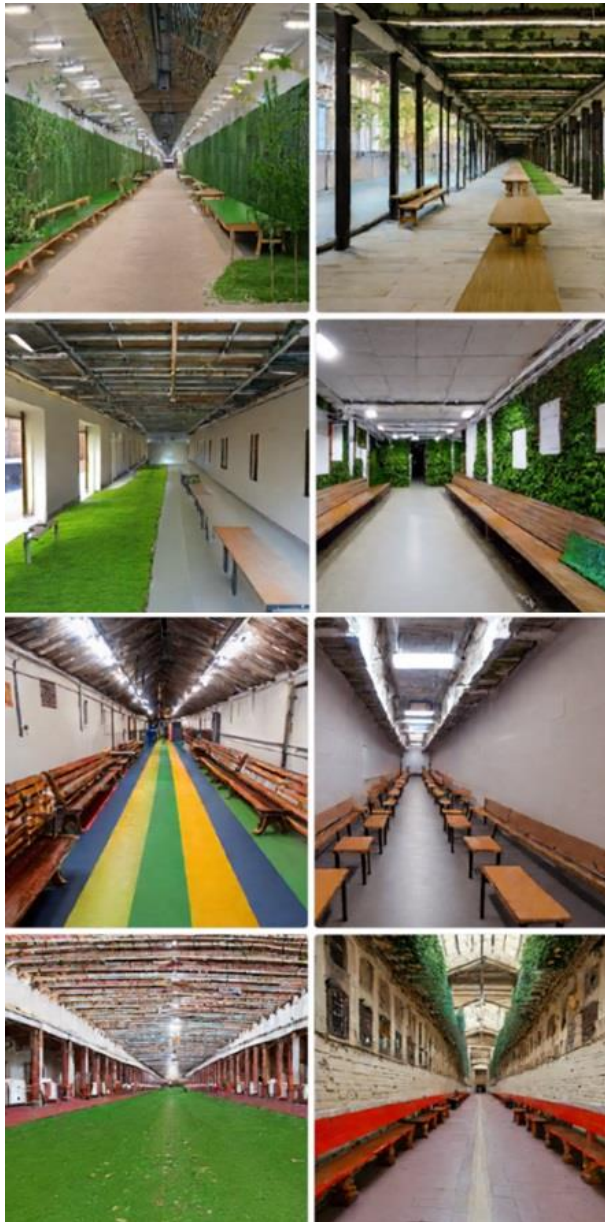
Box 11

Figure 11
Images obtained from Stable Diffusion Web
Source: Own elaboration

IAG Blue Willow (Fig. 12).

Prompt utilized: A 26.14-meter long by 7.67-meter-wide corridor bordered by 2.5-meter-high walls on each side and a ceiling with rectangular white light fixtures. Each wall is divided into 8 sections by columns, the walls will be painted in ivory color, and each wall will have green and blue graphics representing a camera, a microphone, and headphones formed by a continuous line along the wall. In the center of the corridor.

Box 12

Figure 12
Images obtained from IAG Blue Willow
Source: Own elaboration

IAG Adobe Firefly Beta (Fig. 13).

Prompt utilized: A school corridor bordered by walls on each side and a ceiling with rectangular white light fixtures. The walls will be painted in ivory color and each wall will have green and blue graphics representing a camera, a microphone, and headphones formed by a continuous line along the wall. In the center of the corridor, there will be 6 square wooden tables with wooden benches.
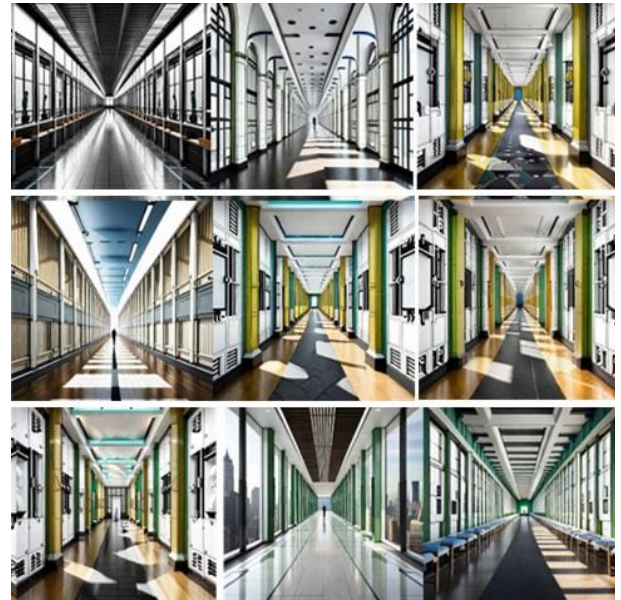
Box 13

Figure 13
Images obtained from Adobe Firefly Beta
Source: Own elaboration

Physical model (mockup)

Models in architectural design are visual and tactile tools that allow architects and designers to represent their ideas and projects in a three-dimensional way. They are useful for visualizing and communicating spatial concepts, volumes, proportions, and architectural details in a more tangible and understandable way. Furthermore, the models were the evidence that allowed us to evaluate the relationship between the different elements of the design, facilitate the visualization of the academic exercise's results, and determine whether the communication with the users and all those involved in the architectural project's design was effective. That is why, behind all the information provided by the communicologists and the search for ideas with IAG, the architecture students proceeded to make a model, scale 1:25. Where they expressed their ideas/concepts and allowed us to distinguish the evolution of the final idea/concept (Fig. 14).

Box 14

Figure 14

Products of the third stage of Architecture students, Universidad Veracruzana
Own source

Software and IAG combination

Finally, we have experimented with the use of the SketchUp software, which works as a rendering tool, where the basic shapes of the 3D model must mainly be made so that, using its plug-in, Veras can determine the details that will be added through the prompt.

The interface called Veras, an AI-powered visualization plugin for SketchUp®, Revit®, and Rhinoceros®, uses the geometry of your 3D model as a substrate for creativity and inspiration, with the use of PROMPTs (instructions) that influence the results obtained by the IAG, which seeks to represent the instructions in 3D view.

According to its creators, Veras is not a simple rendering tool. They define it as an exchange of "ideas" between architects and designers who seek to complement and iterate in seconds to refine the options and obtain innovative solutions. As the program manual indicates, first, the student models the building structure or form, opens the Vera platform, and enters the prompt (Fig. 15).

Conclusions

Semiotics and semantics are fundamental concepts in architectural design. They facilitate the effective communication of meaning and establish connections with users. By consciously incorporating this knowledge, architects can create social and community environments that resonate with users and elicit meaningful responses.

In addition to this, we integrate the management of communication techniques, such as Branding, which facilitates clearer communication patterns and reduces noise in the interaction between architectural design and user needs. However, this document must be prepared by a specialist and may not always be provided by the client. Through these elements, we can establish the corporate identity of the social space to be remodeled, viewed from a marketing perspective.

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Box 15

Figure 15

Images obtained with SketchUp Software and IAVeras
Prompt used: concrete hallway, grassy area, ivory
walls, aluminum windowpanes, wooden doors, wooden
tables, stairs at the end of the hallway.

Source: Own elaboration

No AI application

In relation to the results of communication between individuals informally and formally, we can say that the first allows us to create an excellent concept attached to what the user is looking for; however, the creation of ideas graphically is still limited by the architectural apprentice and the techniques that have not been used.

When waiting for the brief and with the information already obtained, creating the model is undoubtedly the best result for presenting the idea. This type of exercise puts in context for students the difficulty of managing communication with the user and all the processes that have to be carried out without any noise. In addition, it opens the way so that when using 2D and 3D representation software, they can realize their idea in the expected way since, if noise appears in the communication, the student cannot really execute the idea.

The important points that the students expose in this experience and academic activity are the difficulties that can be had with the user's communication, both formally and informally. This helps the student foster empathy and social skills, as well as impartial and expeditious responses, which every architect should have, and educational programs should encourage.

AI application

It has been observed that utilizing artificial intelligence in image generation could offer a promising avenue for exploring linguistics in architectural learning and facilitating the ideation process through guiding images. However, the results are far from a conclusive project for delivery, which is why it allows us to create concepts, but they must be worked on to reach a final product. The results vary depending on the AI used because the programming language used is unknown. This disrupts the writing and the expected result. The discrepancy may arise from the student's limited proficiency in technical language or disparities between contexts, resulting in significant interference.

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The context can influence images, that is, the collective consciousness of the images or the fashion in which this information is immersed. Even the IA website reports that the results are only based on information obtained from recent years; they vary according to the selected IAG. The students commented concerning the use of the IAG that the results can be delayed, depending on the cost of the service, and that experimentation can be frustrating when seeking a specific objective and, in this case, the development of interior design projects, preferably it is better to work previously with a 3D model; report that the generation of external shapes is more accessible to conceive with the IAG.

Applied in the learning process, the students understood the difference between informal and formal language and how communication aspects become more specific and directional from the user, regardless of a project's technical or regulatory restrictions. Communication between user-architect-AI is an unavoidable link in design; until now, the architect must interact with the AI as a bridge between the clients. It is significant to highlight the importance of ethics in using these tools and establish whether we are information providers, communication tools, or content creators since the results are language models mediated by AI.

The emergence of a need is the beginning of every communication and architecture project because it represents the opportunity to create an innovative and highly functional solution. The materialization of an architectural project, from its initiation phase to the remodeling processes, requires methodological steps that encompass criteria of the trinomial: functional, aesthetic, and structural, and currently, the environmental aspect is adhered to. Initially, it is necessary to define the nature of the project and begin with the analytical phase that involves physical context conditions, program determination, and cultural and social conditions.

This is where the generation of ideas begins, where concepts are born, rooted in technique and geometry. These ideas can be translated into architecture through concepts founded on the integration of elements and design principles. However, throughout the process, linguistics (meaning-signifier) plays an essential role in guiding proposal development.

For instance, prior to modernism, projects adhered to a set of rules, codes, and lexicon, where the resulting work ensured its permanence through dialogue. Subsequently, modernism introduced new languages, influenced by the architect's personal temporal context and their degree of openness to external influences, culminating in the digital age (Muñoz-Cosme, 2018). At this stage, the incorporation of digital tools alters the perception in the methodology of stages two and three. As Champitaz (2020) suggests, client interaction constitutes the social aspect of design, a linguistic language that must be loaded with empathy and assertive signifiers of the two previous stages, which cannot be replicated with AI.

In the present study, the results of an academic exercise that integrates three types of communication channels: User-(informal communication)-Architect, Architect-(formal communication)-AI, and User/collaborator-(formal communication)-Architect. This integration aims to gather students' assessments, determine potential improvements in the teaching model, and responsibly and ethically promote the use of AI tools in learning strategies, without sacrificing skills such as the ability to efficiently conceptualize space in three dimensions.

The primary contribution involves integrating multidisciplinary teams in project development, optimizing execution times, and maintaining effective communication with users while utilizing AI tools.

Declarations

Conflict of interest statement

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Grajeda-Rosado, Ruth María: Conceptualization, architectural formal analysis, funding acquisition, research, methodology, software, visualization, writing: original draft, writing: review and editing

Article

Abbreviations

AI	Artificial Intelligent
GAI	Generative Artificial Intelligence
LLM	Large Language Model

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Proposal of a conceptual matrix to present the state of the art of a research to based on the systematic literature review methodology

Propuesta de una matriz conceptual para presentar el estado del arte de una investigación a partir de la metodología de revisión sistemática de la literatura

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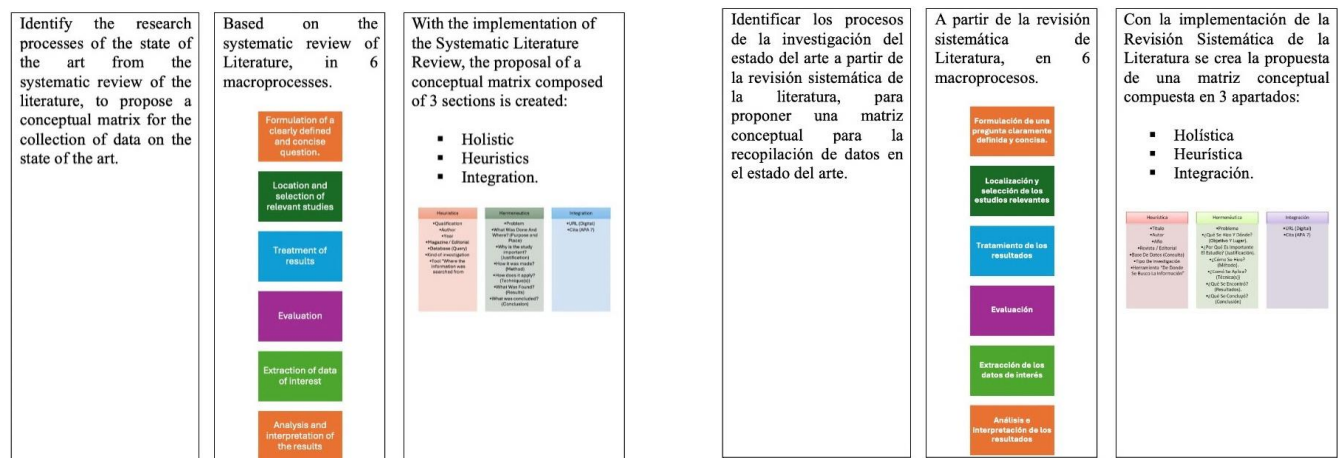[c] ROR Secretariat of Public Education • HDN-0577-2022 • 0009-0007-7120-3883 • 1339276

Abstract

This article presents a proposal for organizing literature in a visual sieve based on a conceptual matrix based on the application of the Systematic Review of Literature methodology and integration of information within the three phases of the scientific method of research to manage a state of the art or state of knowledge.

Resumen

En este artículo se presenta una propuesta de organización de la literatura en un tamiz visual basado en una matriz conceptual a partir de la aplicación de la metodología de la Revisión Sistemática de la Literatura e integración de la información dentro de las tres fases del método científico de investigación para gestionar un estado del arte o estado del conocimiento.

Matrix, Review, Systematic

Matriz, Revisión, Sistemática

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Registro Nacional de Instituciones y Empresas Científicas y Tecnológicas
1702902 CONAHCYT

Article

Introduction

In higher education institutions, in accordance with Article 2 of the General Law of Higher Education, published on April 20, 2021 (General Law of Higher Education, 2021), the facilities are established to carry out research work as part of their training process, which in some institutions is carried out during and at the end in the context of their comprehensive training and in accordance with a process to obtain the degree of studies, due to the above and considering that this process is carried out in several stages and proposing a form of organization, systematized at the time of carrying out the research work and that allows solving the research question by addressing the problems detected.

For the educational experience in higher education of research methodology, there are several authors who describe step by step how the scientific method composed in phases can be carried out, in this case Cesar A. Bernal was taken as a reference in this research process.

In the proposed scientific research method, 3 phases are considered; In the process of searching for information (heuristic phase), investigative actions are carried out on the literature based on empirical knowledge. The implementation of a methodology based on systematization allows us to avoid biases in the research, delimit the topic to be addressed, organize the search in an orderly manner and organize to manage previously established knowledge and answer the research question during the hermeneutic phase.Due to the above and once the exploration and interpretation of the applicable literature has been carried out, a tool based on a conceptual matrix is required for the integration phase that allows the author to document the themes (axes) of his or her research. and organize the information collected by integrating the most important data and present its report (state of the art or state of knowledge) within the research document.Based on what is established in the Systematic Review of Literature (RSL) of the topic, a proposal for organizing the literature in a visual screen based on a conceptual matrix (MC) is presented based on the application of the methodology (RSL) and integration of information within the phases of the scientific research method to manage a state of the art or state of knowledge, which allows the researcher (in this case higher education students) to prepare their reception experience report, dissertation or thesis as part of the construction of their educational experience to obtain the academic degree.

This document is made up of five sections: 1 Context, 2 State of the art, where the methodology of the Systematic Review of Literature (RSL) will be addressed to organize the information in a conceptual matrix (CM) and the authors cited in research methodology subjects; 3 The RSL methodology to prepare this document is described; In 4, the methodology used is developed step by step, and in 5, the result of the RSL is presented through the proposal of a tool to integrate the literature review and facilitate its integration for management and construction. of advances to present the state of knowledge or state of the art in research.

Context

In the subject of Research Methodology taught in higher education, most of them take Roberto Hernández Sampieri as a reference, however; Who also makes a great contribution to the scientific research method is Cesar A. Bernal who shares important material so that step by step the result of the search for information can be reached and both can contribute to the construction of the state of the art or state of knowledge , however; How can this section of the research be managed in an orderly and graphic way to have an overview of previously documented knowledge.

This is where the bases of this research are established to carry out an RSL based on the Scientific research method and the need to establish an instrument that allows collecting information from the literature review for the construction of the section of the research is identified. State of the art or State of knowledge (according to authors) to integrate the information and write in a practical way the report of the section of this stage of the research.

State of the art

According to the book "Guide for the preparation of your research project" by Dr. Gonzalo González Osorio, it addresses an example of digital competencies in new undergraduate students. a university regional for teachers, takes into account the methodology based on the RSL and in which it proposes the use of graphic instruments for the organization of documented information, within the research method it takes Cesar A. Bernal as a reference. (González, 2022). According to Cesar A. Bernal in his book "Research Methodology" he proposes a dispersed methodology to contribute to the purpose of training people with aptitudes and skills for scientific research. (Bernal, 2010)

In accordance with the General Law of Higher Education published in the Official Gazette of the Federation Published on April 20, 2021, the regulatory framework is established in its article 2 to comply with the obligation of the state and contribute to social, cultural, scientific development. , technological, humanistic, productive and economic of the country through people in the field of research, as well as in article 7 in the comprehensive development of students in relation to the above. (General Law of Higher Education, 2021). Based on the text "Hermeneutics and heuristics as scientific methods in medical education" by Sani, Oropeza, Marañón, Puentes and Puentes, theoretical and practical aspects related to hermeneutics and heuristics as scientific methods for their contribution in education are analyzed. professional through a training and research process that enriches the theoretical-practical and scientific-cultural heritage with a totalizing approach to the human being. (Sani, Oropeza, Marañón, Puentes y Puentes, 2021)

In the article "Uses and purposes of ePortfolios" by Lourdes Guardiáa, a guide to the decision process for the implementation of digital portfolios is mentioned through a conceptual matrix understood as the support for the development of a diagnostic and projective tool applying a qualitative research method called Integrative Literature Review subjected to expert validation. (Guardiaa, 2015)

In the article "Methodological strategy to develop the state of the art as a product of educational research" by Carlos Enrique and George Reyes presents a proposal for prepare the state of the art based on an analysis of its conceptualization, presenting an ordering scheme that can help consolidate the state of the art categorized into five moments: 1. Seed, 2. Approach to the study objective, 3. Context and inventory, 4. Analytical, 5. Interpretative. (Henry, 2019). In the bulletin "Systematic literature review: Fundamental concepts" of the University of Seville Library, with the purpose of answering the research question, a systematic and explicit process is proposed to identify, select and critically evaluate relevant research; Initially it was developed for issues related to the healthcare environment, but today it is applied to different scientific areas. (University of Seville Library, 2020)The "State of the art on the subject of graphic organizers in the representation of diagrams and diagrams" by Frank Edison Guerra Reyes & Miguel Edmundo Naranjo Toro shows a product of the usual search for compilation of documents of the different types of diagrams that are necessary to develop graphic organizer assets in which signs are used.

Learning to develop the use of images, color and concepts. (Guerra & Naranjo 2016)

In the book "The state of the art and the theoretical framework in research: A basis for the development of degree work" by Angélica María Alzate Ibáñez & Desiderio López Niño, the aim is to provide young researchers with evidence from theory and practice. about how an accurate review of the literature leads to building a state of the art and a theoretical framework, these components being the first stage of a research for the development of a degree work; Likewise, it provides the tools for students to begin their research work. (Alzate & López, 2018)

Methodology to be developed

Based on the "Guide for the preparation of your research project" by Dr. Gonzalo Gonzáles Osorio (González, 2022), the RSL methodology was taken up for the collection of information in decision making according to the bulletin " Systematic Reviews of scientific literature: fundamental concepts" (University of Seville Library, 2020) shares 6 steps to carry out the systematic review:
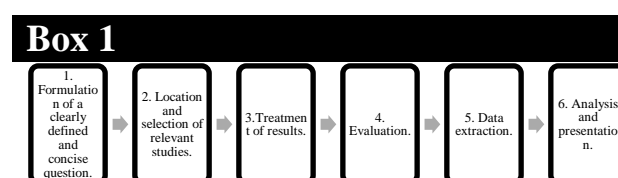

Box 1

1. Formulation of a clearly defined and concise question. → 2. Location and selection of relevant studies. → 3.Treatment of results. → 4. Evaluation. → 5. Data extraction. → 6. Analysis and presentation.

Figure 1
Systematic Review Methodology
Source: Own elaboration

Formulation of a clearly defined and concise question. The reasons why we need a response will be established. Most authors recommend following the components of a PICO question: population, intervention, comparison, out-come.

Location and selection of relevant studies. through a systematic search that identifies all relevant studies. In relation to sources, it is advisable to use at least one multidisciplinary bibliographic database, one specific to the area of study and an open search engine such as Google Scholar. In addition, detailed searches in related journals and manual searches of the so-called "gray literature" (bibliographic references, doctoral theses, communications to conferences, reports from public or private institutions, unpublished works or published in non-indexed journals, etc.) should be included. .). The exhaustiveness and rigor of the literature search will largely determine the quality and final validity of the review.

Treatment of results obtained from the search. Documents obtained from all search strategies should be exported to a reference manager (EndNote, Refworks, Mendeley) that allows the elimination of duplicate articles or articles found in several sources or with several search strategies.

Evaluation of the validity of the results of the included studies. Researchers must establish which of the recovered works will finally be included in the review, developing a list of inclusion and exclusion criteria that should be as objective as possible. To avoid the so-called selection bias, it is important to apply these criteria rigorously to each study, and it is recommended that this evaluation be carried out by several evaluators.

Extraction of data of interest, based on the type of study and the object of the research question. In each of the original articles that are reviewed, information of interest must be sought regarding the characteristics of the studies (design, inclusion/exclusion or selection criteria). cases and controls, selection period, follow-up period, randomization, type of intervention, etc.), to the characteristics of the study population, to its methodological quality (including the statistical analysis methods used) and to its results, with special emphasis on the description of the effect variables of interest. As in any other research project, it is advisable to prepare a form with the data that must be recorded for each work and that the data collection be carried out by more than one researcher, in order to evaluate the consistency of the results and agree on discrepancies.s.

Analysis and interpretation of the results, systematic presentation and synthesis of the characteristics and results of the included studies.

Development

For the first step, the question "Will there be a literature compilation instrument for the management of the state of the art or state of knowledge based on the Systematic Review, applicable to the scientific method?", based on this approach, was carried out. The Systematic Literature Review was carried out using the Connected Papers, Scholar Google and Google tools. Likewise, the ResearchGate, Redalyc, and ScienceDirect databases were used to carry out the review of the literature related to the research topics (words keys).

In the second step, articles that were closely related to the information being sought were selected, giving priority to research no older than 5 years and that had a relationship with the proposed author (Cesar A. Bernal), that were oriented to the scientific method. (phases), which included conceptual matrices in their research, as well as a proposed research method for knowledge management. In the third step, the information was organized in the proposed tool (conceptual matrix), starting from the general to the particular; Likewise, the instrument (ANNEX) was designed based on elements that were found in the same research, which were helpful in the preparation of this research document.

En el cuarto paso se fueron respondiendo preguntas que ayudaron a elegir que literatura would be necessary to present in the report, which were applied in the following way: What was done and where? (objective and place), Why is the study important? (justification), How was it done? (method), What was found? (results), What was concluded? based on the macro description process proposed by Dr. Gonzalo González Osorio in his book "Guide to develop your research project" (González, 2022).

In the fifth step, the concentration of information was carried out in a collection instrument based on the Conceptual Matrix, which is divided into 3 parts (Identification of the literature, Description of its content and Reference). For the last step (step six), the information integrated into the proposed Conceptual Matrix was considered to carry out the analysis and interpretation of the literature; in which, the information resulting from the RSL applicable to this document was integrated in section two.

Results

This document can be identified from the regulatory review applicable to higher education to promote research in study plans and programs, to identifying a methodological proposal that can be integrated into the subject of research methods, likewise it is proposed from the complexity and recursivity how to approach the scientific research proposed by Cesar A. Bernal so that, through RSL, the collection of information, its integration and interpretation can be carried out in an orderly and systematic manner through a conceptual matrix that allows the result of the review to be presented in a sieve and integrate the State of the art or State of knowledge section of a research as part of the management of the information necessary for this stage of the research process of higher education students.

Conclusions

This document proposes the use of a tool applicable to higher education students in their research process to obtain a degree, which compiles the necessary sections that can be used to facilitate the process of integrating information in the management of the state of the art or knowledge in the research process; Likewise, this can be improved by having previous steps according to the scientific research method, which can be investigated in greater depth in subsequent works until integrating a general tool that can guide students step by step in the construction of their research instrument and allows its review, monitoring and construction from a systematic and recursive perspective.

Furthermore, this work will be used as a starting point and conceptual basis for the development of proposals that contribute to different training actions in research methods. The proposal presented here aims to become a projective tool aimed at improving current practices based on a conceptual matrix and the Systematic Review of Literature.

There may be improvements in future work to be carried out to apply with high school and higher education students in order to facilitate the teaching-learning process on the topic of Research Methods and take advantage of the use of information technologies..

Anexos

Box 2

Figure 2

Proposal of the Conceptual Matrix to present the state of the art of a research based on the Systematic Literature Review methodology.

Source: Own elaboration

Declarations

Conflict of interest statement

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

*Mendoza Ruiz, Irving***:** Developed Title of the article, context, state of the art, methodology, development, results, conclusions, references.

Antonio-Vidaña, Paula: contributed to the introduction, the annex of figure 1.2, conclusions, translation of the document and requirements for its publication.

*Cabrera-Ortega, Kristal***:** Participate in the development of the state of the art, development of the methodology, analysis of the results, references and translation.

Availability of data and materials

Guide for preparing your research project.

Research Methodology administration, economics, humanities and social sciences.

General Law of Higher Education.

Hermeneutics and heuristics as scientific methods in medical education.

Conceptual matrix on uses and purposes of eportfolios.

Methodological strategy to develop the state of the art as a product of educational research.

The systematic review of scientific literature and the need to visualize research results.

Systematic Reviews of the scientific literature: fundamental concepts

State of the art on the subject of graphic organizers in the representation of schemes and diagrams

The state of the art and the theoretical framework in research: a basis for the development of degree Works.

Financing

The research did not receive any type of funding for its completion.

Article

Acknowledgements

Abbreviations
MC   Conceptual Matrix
PICO   Population
RSL   Systematic Revision of Literature

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Antecedents

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Basics

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Megatrends as a factor of innovation and their influence on sustainability from a university perspective

Megatendencias como factor de innovación y su influencia en la sostenibilidad desde una perspectiva universitaria

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Abstract

The objective of this research is to analyze the influence of innovation on the social, economic, and environmental dimensions that make up the sustainability of a higher education institution in Sonora from the student perspective.This turns out to be quantitative cross-sectional of a non-experimental and correlational nature, the results are analyzed the effects that innovation has on the dimensions of sustainability through a structural equation model in the Smart PLS statistical program.In addition to this, higher education students were chosen as part of the sample, since these turn out to be one of the main interest groups that are dedicated to addressing sustainability, as well as the main clients of the innovation processes that They develop within organizations, in this particular case, universities. Likewise, it was defined that the type of sampling applied was non-probabilistic for convenience. The above has the intention of contributing to the stock of scientific knowledge and reducing the knowledge gap between both variables, identifying the need to continue developing research based on it, as well as exposing empirical references for future experts interested in the same lines of research.

Resumen

La presente investigación tiene el objetivo de analizar la influencia de la innovación en las dimensiones sociales, económicas y ambientales que conforman la sostenibilidad de una institución de educación superior de Sonora desde la perspectiva estudiantil. Esta resulta ser de corte cuantitativo transversal de carácter no experimental y correlacional, los resultados se analizan los efectos que tiene la innovación sobre las dimensiones de la sostenibilidad a través de un modelo de ecuación estructural en el programa estadístico Smart PLS.Aunado a ello, se eligieron como parte de la muestra a estudiantes de educación superior, ya que estos resultan ser uno de los principales grupos de interés a los cuales se avoca en atender la sostenibilidad, así como los clientes principales de los procesos de innovación que se desarrollan dentro de las organizaciones, en este caso particular, las universidades. Igualmente se definió que el tipo de muestreo aplicado fue no probabilístico por conveniencia. Lo anterior, tiene la intención de contribuir al stock de conocimiento científico y reducir la brecha del saber entre ambas variables, identificando la necesidad de seguir desarrollando investigación en función de ello, así como exponer referentes empíricos para futuros expertos interesados en las mismas líneas de investigación.
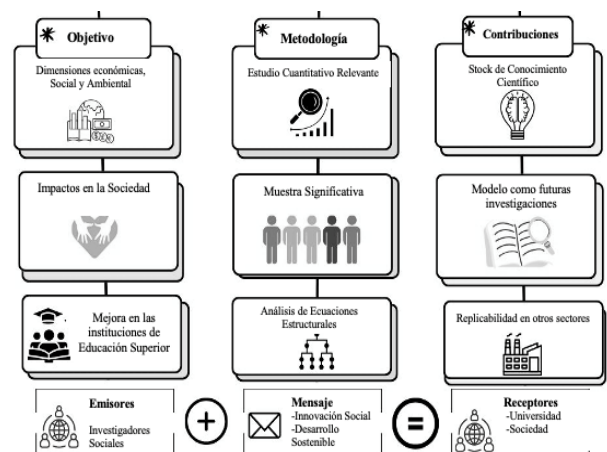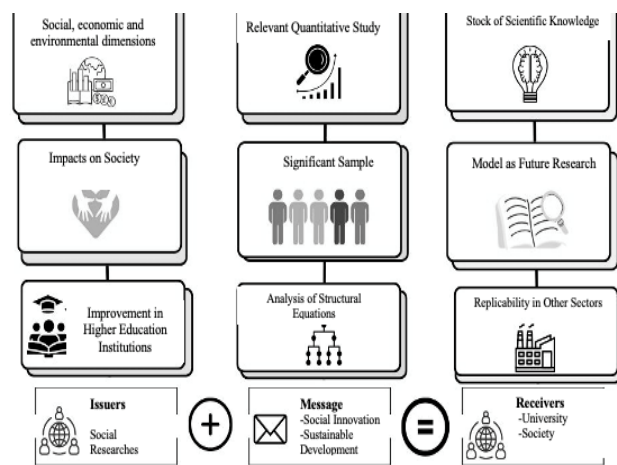
Sustainable Development, Structural Analysis, Social Change

Desarrollo Sostenible, Análisis Estructural, Cambio Social

Article

Introduction

The environment is currently undergoing constant change through natural processes due to human influence. These changes can be perceptible in the short term, long term or medium term, as well as have a significant impact on our quality of life. Pérez-Vallejo et al. (2017) mention that it is currently known that organisations function as open systems, which implies that they operate in dynamic scenarios with respect to the environment that surrounds them, bringing with them a series of constant movements that lead them to generate a high capacity for response and adaptability in the face of these challenges.

This is why organisations are one of the main stakeholders in remaining attentive to these changes that impact the environment. This is where the importance of being informed and prepared to face these transformations lies, leading them to remain constantly updated with respect to the trends that ensure their adaptability, thus guaranteeing a sustainable future (Aponte, 2017; García et al., 2022, Villarreal et al., 2023).

De Faria (1983) defines change as "the modification of a state, condition or situation", thus understanding that a change is any alteration or transformation of characteristics, dimensions or aspects that are significant for the environment. However, it is important to differentiate that there are different terminologies or concepts referring to change: there are superficial changes, immediate changes, medium-term changes or changes with a long-term vision, better known as megatrends.

A megatrend are those "social, technological, cultural, economic, environmental and institutional changes that are long-standing and, once embedded in the system, have a lasting and significant effect on government and society" (Gauna, 2019, p. 15). The importance of studying megatrends dates from the relevant information that can be obtained about future changes through the statistics that this type of study generates, allowing us to know percentages, increases and decreases in an endless number of issues that have a significant impact on our society.

There are several authors who categorise megatrends according to their area of application, such as Alarcón (2016), Martínez and González (2018) and García (2022), who classify megatrends according to social, technological, educational, health, environmental, etc. aspects.

However, over the years, experts have managed to agree on the imminent inclination to generate trends that respond to the different needs of the environment, emphasising a sustainable approach.

In view of this position, organisations, regardless of their line of business, have in recent years focused on appropriating the implementation of innovative proposals in order to meet the needs of society without neglecting the guidelines of sustainability, and in turn, higher education institutions have not remained on the sidelines, joining this new vision in favour of social change.

This is how a new gap is opening up for innovation practices within universities in collaboration with sustainable development. The growing interest in promoting sustainability in higher education is a trend that has emerged in response to the growing concern for the environmental and social problems facing our society. More and more educational institutions are incorporating courses and programmes with multidisciplinary approaches that address environmental, social and economic issues. This allows students to acquire knowledge and skills that enable them to address sustainability challenges effectively. (Belda y Pellicer, 2019; Walker, 2020; Ermólieva et al., 2019; Semanate-Quiñonez et al., 2021).

It is clear that innovation and sustainability are two fundamental aspects that need to be addressed comprehensively in universities. The implementation of innovative and sustainable strategies makes it possible not only to improve the quality of education, but also to contribute to the sustainable development of society. Universities have the responsibility to train professionals committed to caring for the environment and capable of generating innovative solutions to current and future challenges (Rojas, 2022). In this sense, universities assume a crucial role in the achievement of sustainable development goals and in the training of leaders capable of transforming the world for the benefit of present and future generations.

In short, trends in higher education reflect a growing awareness of the importance of addressing environmental and social challenges in a holistic manner. The inclusion of sustainability issues in curricula, the promotion of innovative practices, community engagement, and collaboration with external actors are some of the ways in which educational institutions are contributing to the formation of professionals committed to a future.

Theoretical review

As part of the emergence of the term sustainability, Sánchez and Anzola (2021) mention that it had a predecessor called ecodevelopment, this concept was coined in 1974 by the executive director of the United Nations Environment Programme (UNEP) at the first meeting of the governing council and it was from that decade that the use of terms with reference to environmental topics was triggered.

Sachs (1974) mentions that ecodevelopment is a "type of strategy that is considered viable in several regions of Latin America and that could be useful in regional planning, and especially in the planning of the settlement of uninhabited spaces" (p. 57). According to the author, this concept was aimed at avoiding the waste of resources and minimising the creation of waste.

It was not until 1987 when this concept evolved and a new term called sustainable development was officially presented (Sánchez and Anzola, 2021), which, unlike the concept of ecodevelopment, not only addressed the needs of the current society, but also committed itself to not reducing the possibility of future generations to address the challenges that they could possibly face in the same way, thus generating an imposition compared to the concept of ecodevelopment.

In contemporary terms, the concept of sustainability has emerged in response to social problems and challenges, such as poverty, inequality, climate change and social exclusion. Various organisations and individuals have realised the need to find innovative and sustainable solutions to address these problems, which has led to the emergence of sustainability as an approach and field of study.

Therefore, sustainability can be defined as "a conceptual and ethical vision that, in addition to environmental care and economic development, includes the social dimension: respect for the human rights of all people without exception" (Escámez and Péris, 2021, p. 2). It is thus understood that these technological, social or organisational changes must be carried out under the premise of not compromising the social, economic and environmental well-being of future generations.

This is how this new boom in research began in the 2000s, with organisations such as the Economic Commission for Latin America and the Caribbean (ECLAC) making its first contributions by coining this concept.

Likewise, it is then when the first scientifically rigorous texts were developed, focused on establishing a first approximation to its conceptualisation and to understanding this phenomenon in greater depth (ECLAC, 2024).

Rubio (2006) establishes that sustainability has its origins in globalisation, consumption patterns, overpopulation, global warming, among other world problems. The consequences that this series of problems generate on planet earth and those who inhabit it have led national and international organisations to urgently address these difficulties that compromise the future of the planet. Such is the case of the World Health Organisation (UN), which since 1984 has been working to address the needs regarding pollution and climate change, which was already considered a threat to current and future society, and has been implementing programmes that seek to solve these needs and, over time, have been extended to different sectors in order to improve their practices and work towards sustainable development objectives.

Currently, it is through the 2030 agenda that the sustainable development goals and the action plan to be followed for the next fifteen years in favour of people, the planet and prosperity are known, in order to strengthen universal peace and access to justice, according to the United Nations (2015).

Similarly, institutions such as the Economic Commission for Latin America and the Caribbean (ECLAC) were created in Latin America, which is a mediating body between 46 states for collaboration between Latin American governments that work in terms of research and analysis of the different sectors of the regional and national socio-economy.

Now, according to the UN's 2030 Agenda (2018), sustainability is made up of different areas of development to work on proposals that address needs in different dimensions. These dimensions are defined below (see figure 1).

Box 1
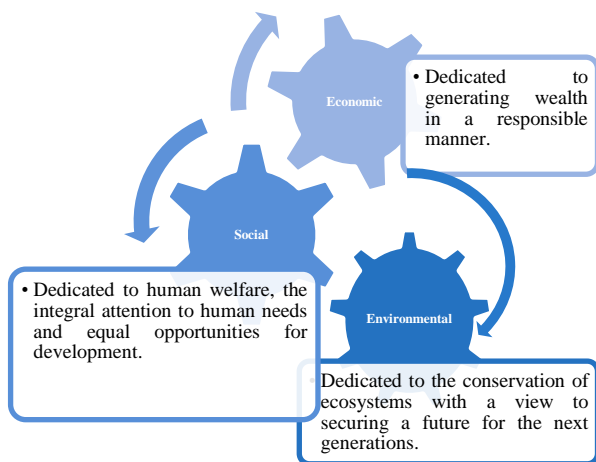
Figure 1

Dimensions of sustainability
Source: Own elaboration according to UN (2018).

In turn, Alarcón and Zepeda (2021) state that the sustainable approach represents an opportunity to reconsider the development strategies of our nations and opens up a new horizon to strengthen the major transformations that will allow us to move towards inclusive, dynamic and sustainable societies. This is precisely the vision embodied in the 2030 Agenda for Sustainable Development, a proposal that distances itself from the conventional vision of development based solely on economic growth.

The notion of sustainable development entails building societies in which well-being, inclusion and equity are fundamental values. The challenge lies in the formulation of models and public policies necessary to facilitate this transition. This is why the education sector has experienced sustainable development through innovation practices that strengthen the collaboration of academia (Casas, et al, 2017; Keck and Saldivar 2016; Monforte-García et al 2016 & González-Gaudiano, et al 2015). Thus, higher education institutions (HEIs) have begun to implement models within their organisational structures and curricula that integrate innovative practices in order to increase their sustainability indexes (Jaca, 2011). Such is the case of Alvarenga et al., (2022) who proposes a model that consists of addressing four main categories within HEIs: 1) organisational philosophy, 2) curriculum, 3) campus and 4) healthy environment, in order to gradually appropriate this new ideology in terms of innovation and sustainability.

Understanding that innovation in universities reflects the ability to generate and apply ideas with creative solutions to address challenges or improve processes within the academic environment, manifesting itself in various ways, such as the creation of updated academic programmes, the implementation of innovative teaching methods.

Promoting research, the development of technology and collaboration between companies, as well as the exchange of knowledge between teachers, students and other educational actors, fostering adaptability and continuous learning, promoting multidisciplinarity, improving educational quality and linking with the environment (Palacio-Fierro et al, 2017; García-Flores and Palma, 2019; Giraldo-Gutierrez et al., 2020; Hernández, 2022).

Therefore, this paper aims to analyse the influence of innovation on the social, economic and environmental dimensions that make up the sustainability of a higher education institution in Sonora from the student perspective.

Hi: Innovation significantly influences sustainability.

H1: Innovation significantly influences the social dimension of sustainability.

H2: Innovation significantly influences the economic dimension of sustainability.

H3: Innovation significantly influences the environmental dimension of sustainability.

Methodology

However, for the purposes of this research, it was established that this is a non-experimental quantitative cross-sectional study and is correlational, as a result of being "a process that consists of discovering and evaluating the existing relationships between the variables involved in a phenomenon" (Rodríguez-Arainaga, 2011, p.50), i.e. it analysed the effects of the innovation variable on the dimensions that make up sustainability.

In addition, it should be noted that higher education students were chosen as part of the sample, as they are one of the main interest groups to which sustainability is addressed, as well as the main clients of the innovation processes that are developed within organisations, in this particular case, universities (Sanz-Hernández and Martínez, 2020).

It was also defined that the type of sampling applied was non-probabilistic by convenience, who Hernández-Sampieri and Mendoza (2018) state that this type of study has the advantage of having greater control over the information to be collected, as it allows for the careful selection of the subjects who will serve as participants; for this reason, the instrument was applied only to those participants who were considered to provide ah doc information regarding the objective established in the research.

Once the participants were determined, it was necessary to identify how the information would be collected. Therefore, it was established that the appropriate instrument according to the interests and the type of questions to be asked in order to obtain reliable information was a questionnaire with response options on a five-point Likert-type scale, where one (1) represented a level of total disagreement up to a level of five (5) of total agreement.

In this sense, for the construction of the questionnaire, a table of operationalisation of variables was developed, by means of which empirical references were identified with respect to the conceptual analysis and the establishment of the dimensions that make up the theme of sustainability, in order to subsequently propose a series of items based on the research consulted and obtaining as a result a proposal for an instrument that allows the variables to be measured.

The content of this instrument was validated by doctoral researchers with expertise in the areas of sustainability, innovation, social responsibility and management, among others. Likewise, a construct validity was carried out through the statistical test Cronbach's Alpha, who Soler and Soler (2012), establish that to obtain significant results the value should range between 0 and 1, the closer it is to 1 means that the instrument is highly reliable (see Table 1).

Box 2

Table 1

Reliability of the variables

	Cronbach's alpha	Cronbach's alpha based on standardised items
Sustainability	.928	.929
Innovation	.783	.784

Source: Own elaboration

From the above, it is understood that the items that made up each of the variables to be studied were reliable, thus allowing the instrument to be applied to the participating subjects and, based on this, obtaining results on the research assumptions established previously.

Results

At the conclusion of the research design phase and the validation of the instrument, it was possible to begin with the application of the questionnaire to obtain data.

Based on this, information was collected from 100 students belonging to different educational programmes offered at the university, with the selection criterion of belonging to a semester equal to or greater than the fifth, since being in semesters closer to graduation, it is understood that they have had a greater approach and experience on the actions and practices that are developed in the institution with respect to the variables of study. Once the data for each participant had been obtained, a database was created in the SPSS statistical programme, which was used to obtain data to characterise the sample (see table 2).

Box 3

Table 2

Participating demographics		
Feature	n	%
Gender		
Female	58	58%
Male	42	42%
Educational programme		
Administration	27	27%
Education	11	11%
Accounting	48	48%
Graphic design	1	1%
Economics and finance	6	6%
Psychology	7	7%
Total	100	100%
Features	M	
Age	21	
Semester	7	
Total	100	

Source: Own elaboration

As can be seen, the average age of the participants is 21 years old, and it is also possible to identify the degree of participation from different educational programmes, where the students belonging to the Bachelor's Degree in Accounting were the ones who participated the most.

Now, as part of the results obtained particularly on the variables of the study, the behaviour obtained with respect to the descriptive data on the variables of innovation and sustainability is shown below (see Table 3).

Box 4

Table 3

Descriptive variables

Variable	Dimension	N	M	Med	M
Innovation	Update	100	3.95	4.00	4
	Models	100	4.08	4.00	4
	Changes insocial value	100	4.11	4.00	4
	Technologies	100	3.96	4.00	4
Sustainability	Environmental	100	4.09	4.00	4
	Economic	100	4.20	4.00	4
	Social	100	4.18	4.00	4

Source: Own elaboration

As can be observed, in both variables and in each of the dimensions that comprise them, the mean response value obtained was equal to or close to four (4), which is a favourable indicator, as it expresses how the responses are located at a good level of acceptance on the Likert scale proposed in the instrument.

Next, the results obtained are presented in order to support the model that was used to test the hypotheses of the study, who Martínez and Fierro (2018) mention that it is required to present test results on internal consistency, convergent and discriminant validity, these tests allow measuring aspects ranging from internal consistency to reach the final results of the acceptance or rejection of the hypotheses, which were generated through the statistical programme Smart PLS.

Initially, to validate the internal consistency it is required to expose results on Cronbach's Alpha, who Gonzáles and Pazmiño (2015) establish that this should be of a value ranging between 0 and 1, being closer to 1 it can be considered that the instrument has a higher reliability. For its part, composite reliability is interpreted by Nunnally and Bernstein (1994) that if FC ≥ 0.7 is a good value, however, FC ≥ 0.8 is ideal. Thus, by meeting both criteria, it can be affirmed that the results obtained with respect to the consistency tests are significantly fulfilled (see Table 4).

Box 5

Table 4

Internal consistency indicators

Dimensions	Cronbach's alpha	Composite reliability (rho_a)
Innovation	0.784	0.792
Environmental	0.897	0.904
Economic	0.816	0.819
Social	0.817	0.818

Source: Own elaboration

Continuing with the consistency results, we present the data obtained with respect to convergent validity (AVE), which allows us to identify whether there is a close relationship between the items that make up the instrument and the theoretical constructs. Henseler et al (2016) establish that an AVE value greater than 0.5 is positive, and consequently, when values ranging between 0.610 and 0.713 are obtained, it can be said that the results are significant.

Box 6

Table 5

Convergent validity analysis

Dimensions	AVE
Innovation	0.477
Environmental	0.593
Economic	0.528
Social	0.527

Source: Own elaboration

The Heterotrait Monotrait Ratio Test (HTMT) allows the correlation between indicators to be analysed. According to Santi-Huaranca et al. (2018) the value must be less than 0.9, and as can be seen in table 10, only some of the values obtained are outside this criterion.

Box 7

Table 6

HTMT discriminant validity analysis

	Innovation	Environmental	Economic	Social
Innovation				
Environmental	0.756			
Economic	0.839	0.655		
Social	0.865	0.870	0.786	

Source: Own elaboration

In accordance with Martínez and Fierro (2018), to determine the factor loadings of each indicator, this must be contrasted between all the latent variables, and must have a higher value with its own latent variable than with the rest of the model (see Table 7).

Box 8

Table 7

Cross-load analysis

	INO	S_AMB	S_ECO	S_SOC
INO1	0.614	0.437	0.557	0.524
INO2	0.667	0.557	0.509	0.581
INO3	0.801	0.571	0.702	0.705
INO4	0.668	0.532	0.541	0.577
S_AMB1	0.566	0.743	0.478	0.643
S_AMB2	0.468	0.616	0.443	0.660
S_AMB3	0.575	0.755	0.500	0.618
S_AMB4	0.694	0.912	0.570	0.769
S_AMB5	0.592	0.778	0.556	0.671
S_AMB6	0.598	0.785	0.457	0.666
S_ECO1	0.642	0.532	0.764	0.605
S_ECO2	0.642	0.368	0.763	0.483
S_ECO3	0.579	0.558	0.689	0.592
S_ECO4	0.578	0.444	0.687	0.594
S_SOC1	0.582	0.532	0.597	0.670
S_SOC2	0.625	0.674	0.493	0.719
S_SOC3	0.663	0.622	0.530	0.763
S_SOC4	0.649	0.696	0.648	0.747

Source: Own elaboration

Results of the innovation and sustainability variables

With regard to the required test analysis to measure the relationship between innovation and the dimensions of sustainability, it was necessary to calculate Path coefficients, which determine the significance of the relationship between the dependent and independent variable, for which Rositas (2005) establishes the following classification: imperceptible (0. 0 > β ≤ 0.09), perceptible (0.1 > β 5 0.15), considerable (0.16 > β ≤ 0.19), important (0.2 > β ≤ 0.29), strong (0.3 > β ≤ 0.5) and very strong (β > 0.50).

Box 9

Table 8

Path coefficient analysis

	Innovation		
Environmental	0.761		
Economic		0.841	
Social			0.869

Source: Own elaboration

Now, as part of the results and once the characteristics of the participants and the necessary tests regarding the measurement model have been exposed.

The following section focuses on developing a verification analysis to evaluate the veracity of the hypotheses raised in the research, by means of the hypothetical model, which is why it was necessary to process the data through the Partial Least Square (PLS) statistical programme, thus obtaining the following graphic.
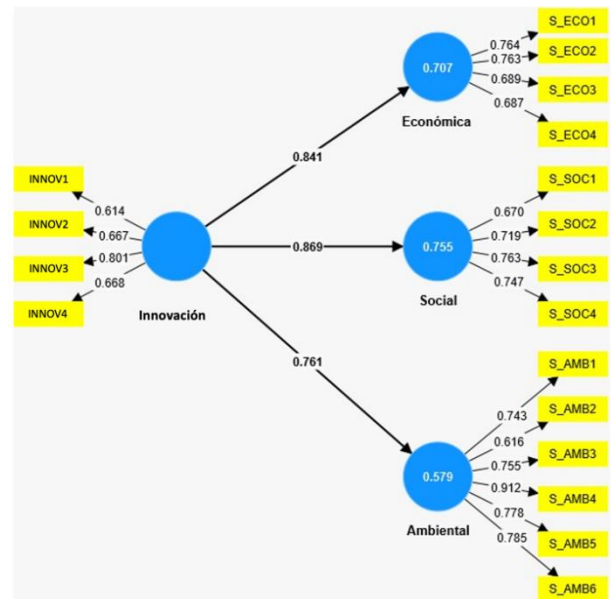
Box 10

Figure 2

Hypothetical model results

Source: Own elaboration

Interpretation of the model

Initially, it is necessary to understand that a structural equation model such as the one presented above allows measuring the degree of significance between the different dimensions of the independent variable (VI) in relation to the dependent variable (DV), in order to determine the importance of the effects generated by each dimension of innovation in sustainability (Ortíz and Fernández, 2018).

Likewise, it can be said that the value of greater significance is referred to as R^2, which is a predictive measurement value, indicating the amount of variance of VI explained by DV. To determine the level of significance Chin (1998) classifies them as follows: R^2 values ≥ 0.1 are weak, R^2 ≥ 0.33 moderate and R^2 ≥ 0.67 substantial.

However, in complex models Hair et al. (2019) stipulates that a value around 0.1 can be satisfactory.Consequently, Figure 4 shows the β obtained for each of the dimensions that make up the VI with respect to the DV proposed in the hypothetical model. It is worth highlighting the fact that the three path coefficients presented obtained a significant result, i.e., it is possible to consider that they have a relevant effect on the DV.

On the other hand, with reference to the result obtained for the first dimension that integrates sustainability, it reached an R2 of 0.707, being a favourable and significant indicator that is classified at a substantial level according to Chin (1998), interpreting a 70% relationship between innovation and the economic dimension of sustainability in higher education institutions, being this percentage whose value contributes greater significance as it is the highest in the model.

In addition to this, the second dimension of sustainability, which refers to the social aspect, also obtained a significant R2 of .755, classifying it at a substantial level and understanding in this sense that innovation does generate a significant effect on the social dimension by explaining 75% of the phenomenon under study.

Finally, the environmental dimension obtained an R^2 of .579, which despite being the lowest result compared to the other dimensions, is still positioned at a moderate level, explaining 57% of the impact that innovation has on the environmental dimension of the sustainability variable.

In view of the results presented here, the acceptance or rejection of each of the hypotheses put forward for this study can be verified, thus analysing their fulfilment, obtaining as a result the acceptance of four of them and the rejection of one (see Table 13).

Given the results presented here, the acceptance or rejection of each of the hypotheses proposed for this study can be verified, analysing their fulfilment, under the acceptance criteria that include the values of the statistical tests: path coefficient, t student and p value (see Table 9).

Box 11

Table 9
Contrast of hypotheses

Hypothesis	Path	T student statistics	P value	Result
Hi: Innovation significantly influences the sustainability of HEIs.				Accepted
H¹ Innovation significantly influences the environmental dimension of sustainability.	0.761 Very strong	9.095	0.000	Accepted
H² Innovation has a significant influence on the economic dimension of sustainability.	.841 Very strong	11.057	0.000	Accepted
H³ Innovation has a significant influence on the social dimension of sustainability.	.869 Very strong	11.512	0.000	Accepted

Source: Own elaboration according to Hair et al., 2019 T student sig. >2.00. Molina, 2017 P sig. value between 0 and 1

Conclusions

This research sought to demonstrate how innovation has a significant impact on the sustainability of higher education institutions. The above results statistically support this assertion, coinciding with the conclusions of Smith and Webster (2018), who conducted a study with the aim of demonstrating and arguing the need for institutions to be constantly innovating, as this will allow them to adapt better and be more sustainable in the face of environmental changes.Furthermore, the acceptance of the hypotheses put forward in this research coincides with Gobble (2012), who highlights the importance of considering the different areas in which innovation can be fostered within organisations. According to him, adopting a holistic perspective on innovation will enable the creation of comprehensive models that address several areas of opportunity within the same entity, thus challenging the long-established paradigm that sustainability focuses exclusively on environmental aspects.

One of the main advantages of sustainability is that it can have a positive impact on the community and society at large. By developing and implementing innovative solutions, organisations can contribute to job creation, sustainable economic development, poverty reduction and social equity (Muñóz, 2020).

At the same time, it coincides with the significant results obtained, allowing the generation of multidimensional proposals that address the needs of the environment more comprehensively, as stated by Medina and Basurto (2018). By visualising a clear classification on innovation, it promotes awareness of creating more effective organisational and management strategies, which increases the sustainability of resources. Under these circumstances, it is recognised that the success of institutions no longer depends on factors such as facilities, production and capital, but on intellectual products, information and knowledge to drive innovation, which impacts on long-term development and increases the importance of intellectual property in modern society.

In relation to the general acceptance that has been achieved regarding the influence of innovation and sustainability, it is important to highlight that both institutions, organisations and companies should begin to consider the commitment to these two areas in their businesses, since the comprehensive vision provided by innovation allows access to new markets, providing greater business opportunities in social, environmental and economic areas (Clouet, & Lozada, 2023).

In conclusion, innovation and sustainability are two concepts that must go hand in hand to achieve economic, social and environmentally responsible development. Innovation drives change and improvement of processes and products, promoting the efficient use of resources and reducing the negative impact on the environment. On the other hand, sustainability invites us to think long-term, considering the needs of future generations and working together with nature rather than against it (Ternéra et al., 2018; Colpas et al., 2019; Uribe, 2020, Flórez et al 2021).

It is therefore essential that organisations embrace innovation and sustainability as two pillars to build a prosperous, equitable future in harmony with the planet. Collaboration between sectors, investment in research and development, and the implementation of appropriate policies and regulations are some of the essential actions to drive this transformation towards a more sustainable economic and social model. This is the only way to ensure a better world for future generations and to preserve diversity, encouraging informed decision-making to contribute to positive change.

Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that could have influenced this article.

Author contribution

Salguero-Cruz, Yizel Carolina: The main contribution he made was the search for information, field work, study of the art and formulation of hypotheses.

Flores-López, José Guadalupe: Generated the methodology, the use of software and results.

Availability of data and materials

The data were obtained through the application of instruments directly to the study subjects.

Funding

Acknowledgements

Abbreviations

AVE.	Convergent Validity
ECLAC	Economic Commission for Latin America and the Caribbean
HTMT	Heterotrait Monotrait Ratio
HEI	Higher Education Institutions
INO	Innovation
M	Mean
N	Sample
UN	United Nations
PLS-SEM.	Structural equation modeling
UNEP:	United Nations Environment Programme
S_AMB	Environmental_Sustainability
S_ECO	Economic_Sustainability
S_SOC	Social_Sustainability
SPSS	Statistical Package for the Social Sciences
DV	Dependent variable
VI	Independent variable

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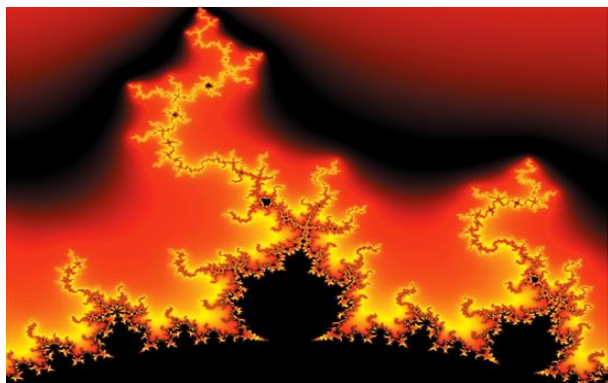[Indicating the title at the bottom with No.10 and Times New Roman Bold]

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