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# EDITOR'S LETTER

February – June 2026

Dear members of the university community, teachers, readers, collaborators: fulfilling our periodicity and raison d'être, we greet you cordially, while thanking you for having accompanied us in these thirteen years of uninterrupted publication. We welcome the year 2026 with this volume 15 of the Journal of Scientific Dissemination *Espacio I+D, Innovación más Desarrollo*, corresponding to the period from February to June 2026.

This year we have witnessed the early advances of artificial intelligence; how paradigms of research and academic publication have been reconsidered and questioned, which is why our editorial policies have undergone some minor modifications, as part of the openness to this no-longer-so-new, but above all to respect for human intelligence and creativity; the modifications can be consulted in the "Publication Guidelines" section.

In this issue, we provide you with articles from various disciplines from national universities, such as: *I Notice, I Wonder. Pedagogical strategy for deeply understanding and problematizing, Educational Policy in Mexico: Analysis of Civic Education in the State of Puebla, Integration of Artificial intelligence in education: Documentary analysis, Synthesis of Zinc Oxide by the hydrothermal method: effect of aging time, Neurotechnology in higher education: An analysis of attention and emotion using eye tracking, Motivational impact of gamification on higher education students from the perspective of Spanish speakers, Osmotic dehydration of Mangifera Indica l. VAR. oRO with high sensory quality, Secondary intestinal intussusception to a GIST tumor in a girl* and *Relationship between academic stress, eating disorders and mental health in University Students.*

From this platform for the dissemination of knowledge and culture at our Benemérita UNACH, we hope to continue contributing through high editorial standards, as we have done thus far, to the communication of science for human development. Finally, this year we invite you to read and collaborate with us on our upcoming issues. From the Editorial Board, the team behind the Espacio I+D Innovación más Desarrollo Journal, we wish you a prosperous 2026.

«*Por la conciencia de la necesidad de servir*»

Editorial team

*Revista Espacio I+D, Innovación más Desarrollo*

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# Articles

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# I Notice, I Wonder. Pedagogical strategy for deeply understanding and problematizing

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*— Abstract—*

I Notice, I Wonder learning strategy was developed by The Math Forum, and it works essentially as a scaffold to promote evidence-based reasoning about a) mathematics and b) the student's mathematical thinking, although its use has extended beyond mathematics and is widely used in the United States, mainly with elementary school children to introduce them to some specific topic. This paper documents the educational experience of applying the I Notice, I Wonder strategy in environments with medical students and teachers, particularly in the Global Health curricular course. A checklist is also presented for its evaluation. Through a narrative analysis of a student's learning journal and written comments by teachers, the usefulness of the strategy is confirmed as an aid to trigger the problematizing competence; however, it requires a co-construction, basic writing skills and critical analysis from students and a willingness from medical teachers in order to get training on the strategy.

**Keywords***:*

*"I Notice, I Wonder"; wondering; noticing; problematize.*

This paper describes an experience regarding the application and educational outcomes of the *I Notice, I Wonder strategy* (Noticing and Wondering, or "*Darse Cuenta y Preguntarse*"). The pedagogical development process began when the delivering author (García-Miranda, GA) first encountered the strategy in the MOOC *Introduction to Data Wise: A Collaborative Process to Improve Learning and Teaching* (Harvard University, USA; 2015), which was employed alongside other techniques to analyze, interpret, and reflect on a set of data, typically numerical.

Initially, the strategy was personally perceived as somewhat repetitive, as it was employed in all the thematic units of the aforementioned course. However, the reflection on the strategy enabled better appreciation of its didactic potential. Based on this experience and reflection in practice, it was decided to implement the strategy in the Global Health course with medical students at the Universidad Nacional Autónoma de México (National Autonomous University of Mexico, UNAM) and the result was encouraging, since the students reported that the exercise caught their attention and that they saw in the strategy a different way of analyzing a text. From that outcome and the experience of applying it to various student groups, it was decided to subsequently employ it in teacher training courses in medicine, and finally, an instrument was developed to evaluate the results obtained.

With the aim of establishing a reference framework regarding the use and utility of the educational strategy, a conventional search was conducted using the terms "I Notice, I Wonder", and various websites were reviewed that promote the use of the strategy and also advertise the sale of support cards to be used in primary school classrooms. Based on the content of the examined pages, it was observed that the strategy is used essentially for children to record their thoughts, to identify students' support needs, to acquire information or clarify some concepts, to learn observational skills and concentrate attention, as well as to foster creativity and the capacity of enquiry. Specifically, it was noted that the strategy is employed to assist children in developing critical thinking and problem-solving abilities in academic subjects such as mathematics and writing. Similarly, it functions to foster explicit observation and open-ended questioning.

Likewise, the I Notice, I Wonder strategy was proposed by the K20 Center for Educational and Community Renewal in Oklahoma as an educational strategy that helps students create good questions based on available information by writing what they notice and what they wonder about a new topic (K20, 2020). Furthermore, they note that the technique can be used to introduce students to a concept, issue, or idea (K20, 2022).

Conducting an advanced bibliographic search regarding the application and evaluation of the didactic strategy in research articles, it was observed that there were few studies on the didactic-pedagogical evaluation of the *I Notice, I Wonder strategy*, particularly in higher education.

It was also remarkable to discover that the strategy was developed by The Math Forum for teaching mathematics and that its application has currently extended to other areas of teaching and educational levels. In Garret and Matranga (2020) the I Notice, I Wonder strategy in mathematics instruction function as a scaffold to develop evidence-based reasoning about mathematics itself and students' mathematical thinking.

Garret and Matranga (2020), based on a conceptual analysis that contrasts traditional teaching centered on information and skills (narrow paradigm) versus an expanded paradigm focused on Access to Discourse and Practices (ADP), present the educational experience of implementing *Noticing and Wondering*. The authors regard the novelty of their contribution lies in the context of K-12 education in United States and share insights derived from the systematic, long-term use of these two pedagogical phrases that encourage thinking and discourse. The authors conceptualize *Noticing and Wondering* as a reference point for instructional approaches that focus on the use of this set of phrases on a consistent basis.

*Noticing and Wondering* is asserted to be an innovative pedagogical strategy with documented effectiveness in mathematics education, while representing potential for other fields of study in embracing a *paradigm of discourse and learning practices* and thus may prove generalized beyond K-12 classrooms. The authors additionally argue that it shows promise for multilingual students. They view *Noticing and Wondering* as a *culturally and linguistically sensitive* tool that can enable teachers to effectively address all students' competencies and needs. It is posited that *Noticing and Wondering* has the potential to create a democratic learning environment where all students have opportunities to participate and learn, even when students may feel less capable than their classmates. The accessibility of *Noticing and Wondering* directly guides teachers and students toward ensuring equitable access for all learners to sophisticated reasoning and language use.

According to Garret and Matranga (*op. cit.*), *Noticing and Wondering* by its very nature, creates a conduit for cultural relevance in the classroom and acknowledgment of students' prior and existing knowledge, as *Noticing and Wondering* constitute expressions of what learners deem personally and culturally meaningful. When teachers invite students to notice and wonder, students' culture and familial discourses are granted a space in the classroom community. Even before the teacher recognizes student input, the act of asking students to articulate what they already know or think about a topic serves as a powerful catalyst for thinking, which is significant for developing student engagement.

On the other hand, Plutino (2021) points out that motivation to learn begins with wonder and that questioning goes beyond curiosity, which the author defines as the drive to explain the unexpected (citing Piaget, 1969) and the drive to know more (citing Engel, 2011). When students wonder, they articulate their desire to know both what they do not know and what they already know. The author notes that *I Notice, I Wonder*, has been effectively employed in elementary education

across various subject areas, primarily in science, technology, engineering, and mathematics. However, her work demonstrates how this instructional strategy may also provide an opportunity in modern foreign language instruction, largely due to the educational challenge that students find it increasingly difficult to develop curiosity about these languages. The author proposes implementing extension activities (such as the creation of a Day of the Dead ofrenda for Spanish language learning) and their integration with "Wonder Pedagogy", noting that when this strategy is employed, both interest and learning are enhanced, as learners become agents of their own learning by generating their own set of questions. The author asserts that the strategy represents an activity that goes beyond the stereotypical image of language learning, instead allowing students to "think outside the box" while establishing connections with other subjects and approaches. Plutino (*op. cit.*) proposes reinforcing such activities at different educational levels and creating inter-institutional networks between schools and universities to foster mutual inspiration and thereby address the limitations of an overly rigid, assessment-focused language curriculum.

Furthermore, Anderson and Dobie's (2022) work investigate how the use of sentence stems, "I Notice" and "I Wonder", operates to promote productive dialogue in asynchronous sessions of an online course for kindergarten through second grade (K-2) teachers. Drawing from teachers' responses to peer reflections in the classroom, the study sought evidence concerning how course prompts encouraging teachers to employ these stems influence the nature of contributions they provide. The authors regard the practice of prompting teachers to share what they "Notice" and "Wonder" about classroom activity representations as a promising direction for future research and practice related to teacher perception in online and offline settings. Similarly, they believe the results offer encouraging evidence that "I Notice" and "I Wonder" can create learning opportunities in which teachers, by engaging with one another's responses, gain exposure to greater variation in perspectives and ideas, thereby generating meaningful impacts on teacher learning and discourse.

The mechanisms for evaluating the results of the *I Notice, I Wonder strategy* have also been different. In Lowe's work, Prout and Murcia (2013) used a reflective journal as part of a teacher exchange experience. Five selected teachers from Western Australia participated in a mentoring project with teachers in Tanzania. Australian teachers spent a month embedded in local primary and secondary schools, working collaboratively with their Tanzanian counterparts. As a strategy to make sense of their experiences, each teacher was asked to keep a reflective journal, using *Harvard's visible thinking routine of "see, think, question*" as a critical structure to guide their journal writing. The primary objective of the research was to examine the effectiveness of the reflective journal as a tool enabling teachers to construct meaning from their teaching practice, particularly in challenging or conflictual instructional situations, and to evaluate the usefulness of the Harvard approach in structuring the reflective process as a component of an action-based model.

Additionally, Watson (2002) describes the application of the strategy in a teacher training process with professionals and practitioners. To evaluate the impact of the exercise, teachers kept journals in which they recorded their reflection-in-practice and thoughts generated through *I Notice, I Wonder*. The narrative analysis of both the journals as a corpus and individual participant narratives led the author to develop his own reflective insights concerning what he noticed in the participants' narratives.

For instance, particular pedagogical trends and concerns: one teacher genuinely questioned how to connect with children, how to establish relationships with them (whether she had been relevant, empathetic, or confusing, whether she succeeded in understanding young people's humor and vice versa). The analysis and feedback regarding participants' journals prompted the author to utilize the twin tools of "Noticing" and "Wondering" in reflecting upon both his own teaching practice and that of his students (pre-service teachers).

Anderson and Dobie (*op. cit.*), in turn, adopted a *discourse analysis* approach in an online course, constructing categories based on discussion forums among teachers, since teachers were prompted to respond to their peers' reflective posts in various course segments.

To make even more evident the spectrum of potential of *I Notice, I Wonder* one can cite the work of Dobie and Anderson (2021), in which the authors present a detailed analysis and guide concerning how noticing and wondering can help structure important school-based conversations. Examples include student thinking, power and participation, and task cognitive demand. Furthermore, they suggest specific contexts in which "I notice" and "I wonder" can be used in both face-to-face and virtual environments.

Therefore, evidence exists that the "Noticing" and "Wondering" exercise holds potential for application across various educational contexts and levels, though scientific evidence remains scarce, especially in higher education. Concerning this matter, Garret and Matranga (2020) conclude that the *I Notice, I Wonder strategy* could be broadly applied in science and that considerable benefit would accrue from conducting an empirical study of its impact. Anderson and Dobie (2022), in turn, assert that while recent publications addressing the utility of *I Notice, I Wonder* have begun to be published, the empirical research base linking "I notice" and "I wonder" to teachers' learning processes remains limited. The authors, based on the proposals of Fukawa-Conelly et al. (2018) and Roller (2019), agree that previous studies have suggested that encouraging teachers to "Notice" and "Wonder" can influence the content and form of their participation in instructional conversations, though the depth and systematicity of these associations are unclear. They further assert that, despite the apparent self-explanatory nature of the 'I notice' and 'I wonder' stems, it remains unknown how frequently teachers take up these phrases, how they are actually employed, and how such use might relate to common challenges in fostering dialogue in teacher professional development environments.

## RESEARCH PROBLEM

Over the course of our teaching experience in medicine, we have become aware that when students are questioned regarding a topic, problem, or situation, the response is typically an opinion or anecdote, regardless of whether the exercise requires analyzing, synthesizing, arguing, or another form of discourse. Additionally, in a situation also encouraged by the curriculum itself, they propose research questions without problematization, either disconnected from theory or merely imitating previous research. The situation has been further complicated by the fact that students face increased challenges in articulating their thoughts and presenting publicly in the post-pandemic era. Additionally, when analyzing cases requiring a holistic problem perspective, their contributions demonstrate a reductionist outlook and are treated from a clinical logic. This context encouraged us to apply the *I Notice, I Wonder strategy* as a means to inevitably establish a reference point for questioning and to facilitate the problematization, organization, and socialization of thoughts.

The present study reports empirical evidence on the implementation of the *I Notice, I Wonder strategy* and a *custom-designed* assessment instrument. The strategy's potential and educational achievements are discussed, and pedagogical reflections are shared concerning the approach applied in medical education with students from different sections of the "Global Health" course at the Faculty of Higher Studies Iztacala, UNAM, in addition to a teacher training group at UNAM and another at the Federal Rural University of the Semi-Arid Region (Universidade Federal do Semi-Árido, UFERSA), Brazil.

### *Objetive*

To describe the experience of implementing and evaluating the *I Notice, I Wonder strategy* and its pedagogical potential in medical training settings, specifically with Global Health course students and medical faculty.

### *Methodology*

#### Participants

The *I Notice, I Wonder* strategy has been employed in the "Global Health" course at the Faculty of Higher Studies Iztacala, UNAM (Mexico); in a teacher training course within UNAM; and, recently, at the Universidade Federal Rural do Semi-Árido (UFERSA), in the faculty training course *Estratégias de Ensino-aprendizagem Innovadoras* (Innovative Teaching-Learning Strategies) (UFERSA: 2022), which developed a set of innovative strategies designed to foster problematization skills, decision-making, and the development of alternative models for representing knowledge and social realities.

## Method

Qualitative research. Longitudinal participant observation in eight Global Health courses for medical students and two teacher education courses. Construction of an evaluation checklist for student exercises, which was the piloted through peer assessment activities among students, as represented in Figure 1, in order to identify the instrument's performance, potential difficulties or gaps, and students' overall perceptions. Following the pilot phase, the evaluation instrument was refined. Content analysis of learning journals from 'Global Health' course students.

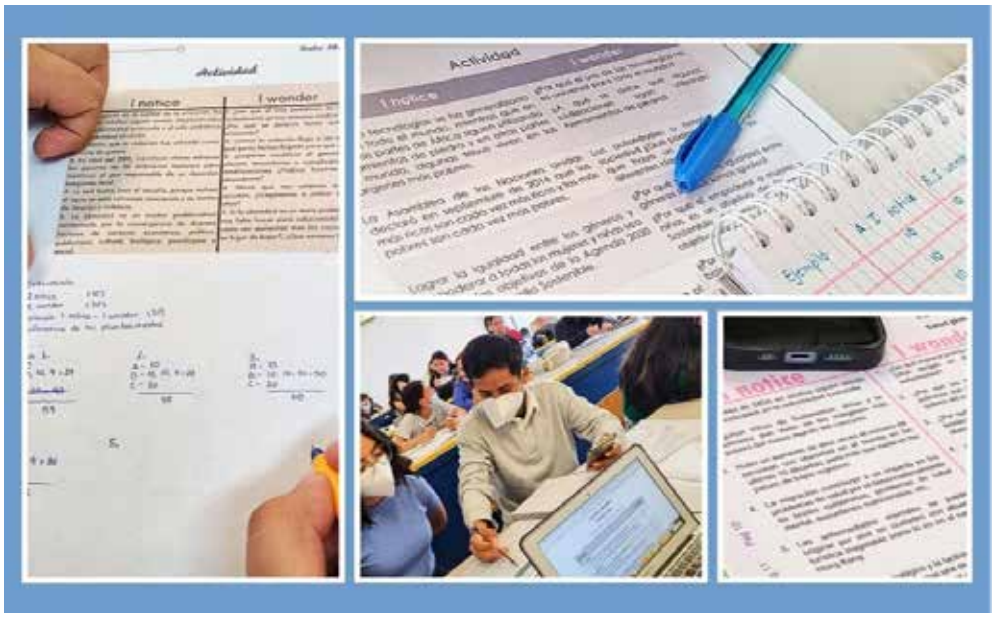


***Figure 1.*** Co-evaluation exercise by the students, carried out with the idea of doing a pilot test of the checklist

## Instruction for strategy development

In the K20 version, students document observations and questions regarding a topic that has been introduced to them only briefly. Subsequently, they share selected items with their peers, and a collective class list is generated that remains accessible throughout the duration of the activity. Upon task completion, students revisit both their own questions and those they initially sought to have answered, verifying that all have been addressed (K20, 2020). This instruction varies from those reviewed in the theoretical foundations. For instance, Anderson and Dobie (2022) provided the following instructions to encourage asynchronous dialogue among teachers in an online teacher education course: "Choose at least two colleagues" reflections to comment on. For each of the two reflections, try using the prompts "I notice..." and 'I wonder...". An additional prompt was "Read at least the reflections of two other colleagues. Share a new idea or question that arises

after reading the aforementioned reflections. If they have formulated a question or identified a challenge, support them in developing possible ideas".

In our practice, students were asked to read an article on global health foundations (García-Miranda: 2019) and then, based on the aspects of the article that most surprised them from the reading, to use the *I Notice, I Wonder* phrases to highlight the events that surprised them and the questions generated by the reading. We implemented this strategy in the "Global Health" course as a formative evaluation tool to assess students' level of understanding or engagement with the reading, as students commonly address text analysis assignments by reading the document, marking what they consider most important, but at the moment of conducting the analysis in groups or in writing, they typically only paraphrase what they have read.

This strategy could additionally be implemented as part of a shared reading activity using a brief text to facilitate discussion of a problematic topic or situation, and to provide a preliminary overview of topic content. When a topic has been previously examined, the visual component can assist in synthesizing the subject matter, problematizing the situation, and uncovering the importance of the reviewed material. Table 1 outlines suggested didactic resources that can be utilized in accordance with particular learning objectives.

**Table 1**

*Resources for the development of the I Notice, I Wonder strategy according to the learning purpose*

| Purpose | Didactic resource |
|---|---|
| Introduce students with a concept, topic or idea. | Short note from a newspaper, video or eye-catching image. |
| Formative assessment of the comprehension of a text. | Article or text of regular length. |
| To determine topics of interest for students. | Short or regular length text. |
| Problematizing an event or reality. | Report of an event, image with brief descriptive text, a case in different formats. |

For recording proposals, participants were asked to develop a "T- chart or table with "I Notice" labeling the left column and "I Wonder" labeling the right column. In Spanish, the phrases "Me doy cuenta, Me pregunto" were utilized, and in Portuguese: "Eu percebo, Eu me pergunto". The exercise can be conducted individually, followed by group sharing to analyze collectively which questions need correction or precision, as shown in Figure 2.

The strategy can also follow an alternative route whereby one question is selected from the collected set for further investigation. Additionally, questions can be analyzed collectively to identify central problematic themes, especially when studying real-world phenomena.

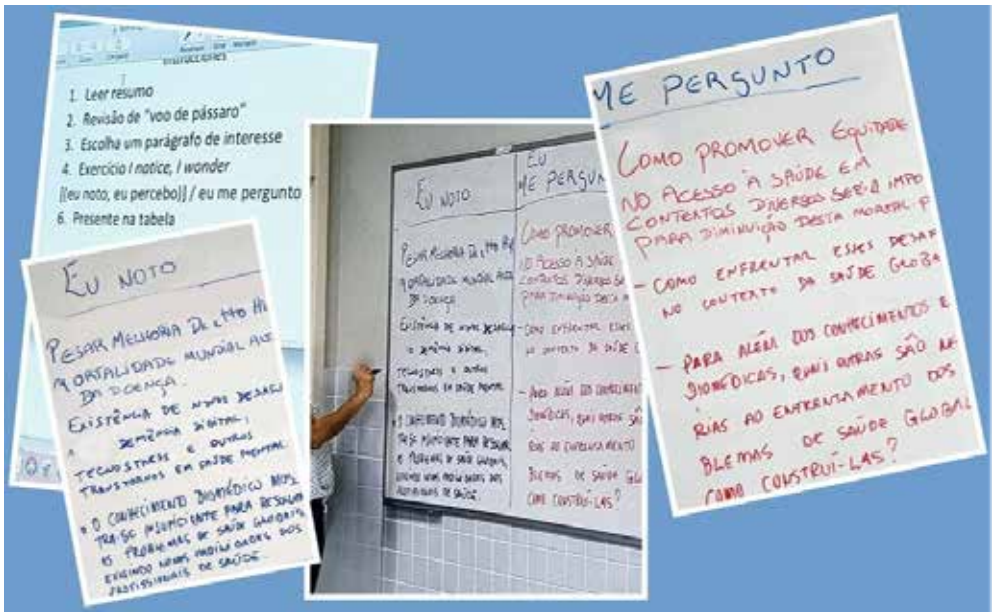


***Figure 2.*** Demonstrative exercise conducted by teachers applying the basic instructions of the learning strategy

*Evaluation of the strategy's usefulness*

Students enrolled in the "Global Health" course were requested to maintain a learning journal (with previous guide) for all course sessions, among which were those employing the "I Notice, I Wonder" sentence stems. Content analysis of the journals was conducted to evaluate the meanings of learning outcomes and identified benefits. Teachers, for their part, were asked to provide comments on the educational value they attributed to the strategy.

*Results*

Given that we have principally utilized the *I Notice, I Wonder strategy* in "Global Health" courses and teacher education courses, though with readings on the same theme, the examples are focused on that subject. Table 2 shows several examples developed by participants and discusses their appropriateness.

**Table 2**

*Analysis of some I Notice, I Wonder approaches made by the participants*

| I Notice | I Wonder | Comment |
|---|---|---|
| The article mentions how children residing in areas with armed conflicts cannot distinguish between a weapon and a camera. | Why, despite the fact that this problem has existed for several decades, has it not been possible to take action regarding children in refugee camps? | In the *I Notice* statement, the student constructed a generalization based on an individual case. Nevertheless, the question is not wholly specific, inclined to be obvious and to constitute a generalization supported by minimal argumentative foundation. |
| The article emphasizes that global health is linked to numerous aspects, including political, economic, social, and cultural factors. | Is there any international law that provides legislative and judicial regulation of human rights violations? | *I Notice* refers to the content of the article read; in this sense it constitutes a pertinent observation. The question is specific and original. |
| Emotional and mental health is a subtopic addressed in the article, in which most developed Eastern countries face these types of problems. In my view, and drawing upon information I had previously read, many of these reasons for this pressure originate from culture and society themselves. | Why is mental and psychological health consistently relegated to last place? What are the appropriate measures being taken by the WHO concerning these issues?<br>Do religious considerations in certain countries constitute an impediment to discussing specific mental and psychological health topics, politics or religion? | This example demonstrates that the participant integrated observations from the article with prior knowledge and generated several questions, indicating the construction of "scaffolding" to create or strengthen new or existing cognitive structures.<br>Here, the value of problematization is substantial, as the participant not only formulated a question but developed a problem nucleus. |
| Currently, scientists have the means and ability to combine genetic species of animals such as zebra-horse, lion-tiger, goat-sheep.<br>Plant species can also be combined fulfilling the whims of the human being, all this is not compared to the greatest desire that is to be able to alter and modify the human organism. | A benefit for humanity or scientific greed?<br>In my opinion, it represents a combination of both, given that it could be utilized to address food crises in vulnerable areas. However, it is uncertain whether scientific communities have been financially supported to conduct this research. | In this task, students make precise observations and ask questions that inform an opinion. Clearly, the question arises from their engagement with the observation. |
| Although I already knew about other genocides throughout history, I was not deeply familiar with their cultural context. | Were these genocides really visible enough so that they do not happen again? | The observation is related to the text read, though it does not constitute a specific observation. The question is pertinent and reflects critical analysis. |
| Addiction to diverse electronic media affecting our health. The article addresses technology addiction, noting the emergence of the so-called "technostress". | Is technological innovation being used in our favor or against us? | The observation is related to the text read, though it does not constitute a specific observation. |

***Utility***

In summary, the overall results of the implementation of the strategy show the following advantages:

- It helps students think critically and avoid making baseless comments.
- It supports the formulation of relevant questions.
- It enables dialogue with prior knowledge and encourages reflection on one's own learning.
- It allows students to explore new knowledge and experiences.
- It contributes to the consolidation of prior or recent learning.
- In terms of formative assessment, reading students' responses allows for conceptual corrections and improvement in the written expression of observations and questions.
- It increases intrinsic motivation to learn by awakening the desire to know more and continue exploring the topic or question. This also encourages student commitment to the task.
- The exercise of becoming aware and formulating questions based on an observational experience generates feelings of doubt, curiosity, and wonder. The world yet to be known expands.
- Combat the dogmatism of reading and rereading for memorization purposes.
- It generates new ideas.

In particular, group discussion after individual work offers the possibility of: a) improving awareness of one's own thoughts and recognizing one's capacity for self-criticism; b) foster appreciation among participants for the diversity of opinion that invariably arises when viewpoints are shared openly and honestly; and c) acting as catalyst for diverse ideas.

In general, professors show less receptiveness to the technique (explained in disadvantages). Nevertheless, there are also instances of professors who are highly interested and willing to participate in innovative strategies. They discover the value of the strategy, as seen in the following excerpts from learning journals of students in the "Global Health" course:

> *"A metodologia do "I notice, I wonder" [...] são ferramentas interessantes para tornar o processo de ensino-aprendizagem menos maçante. Me senti mais confortável no uso da ferramenta "I notice, I wonder", tendo em vista que ela me pareceu mais fácil de ser aplicada no contexto do Eixo Teórico-prático Integrado (ETPI), onde estou inserido como docente. "I notice, I wonder" pode ser utilizada para dinamizar temáticas que os(as) discentes tenham realizado a leitura prévia do assunto por meio de material disponibilizado pelo(a) docente".*

*"A metodologia "I notice, I wonder" e [...] foram o primeiro contato que tive a oportunidade de ter. Apesar de ser tutora de Problem-based learning e estar inserida como docente em um curso cujas as metodologias ativas são o cerne da aprendizagem, a estranheza inicial, talvez pelo idioma da leitura inicial, tomou-me de surpresa, porém em poucos instantes com as intervenções e direcionamentos da Prof. Glória pude contemplar e pensar nas utilidades dos dois novos métodos a mim apresentados".*

*"A metodologia "I notice, I wonder", permitiu-me de forma dinâmica identificar pontos chaves do artigo em questão, ao passo que simultaneamente me estimulou a pensar criticamente com a necessidade de fazer uma pergunta a cada observação escrita. Tal ferramenta pode ser de grande valia para leitura de artigos e discussão em grupos maiores de alunos, proporcionando direcionamento aos pontos principais da leitura bem como proporcionar o desenvolvimento de pensamento crítico ao provocar questões/perguntas sobre tais pontos, que possivelmente poderão fomentar um leque de possibilidades de resolução de problemas".*

*"I notice, I wonder" consiste em identificar pontos extraídos de texto e então problematizá-los através de uma pergunta chave. Com o emprego do método acredito que existirá uma leitura mais consciente além do desenvolvimento de senso crítico pelo grupo".*

**Disadvantages**

Participating students have been observed to experience difficulties in establishing the limits of observation and in overcoming the inclination to provide opinions rather than to problematize. An additional dimension of this limitation in problematization stems from students is the habitual practice of generating summaries as the product or evidence of comprehension when reading documents for assignments. Nonetheless, *I Notice, I Wonder* requires critical judgement for choosing relevant information from the reading and developing questions based upon it. Another limiting factor is the resistance, friction, or tension associated with embracing critical reading instead of uncritical reading founded on repetition and memory. Despite these challenges, the student body is usually willing to carry out the exercise.

Overall, in the case of teachers, their approaches are usually brief and present the same difficulties as with students, although there is also resistance to changing the role of teacher and working openly on the assignment. Most teachers exhibit discomfort at the beginning of the exercise and some of them argue that they are "not accustomed to it". Adopting the student's role proves difficult for them. Teachers identify the usefulness of the technique to apply it with students, but not to develop it personally.

The strategy encourages divergent thinking, which could pose challenges for teachers to guide the process in terms of articulating students' questions and comments in relation to a particular topic while maintaining the limits of the activity's themes and objectives.

In the specific context of the Global Health course, *I Notice, I Wonder* serves as an effective resource for exploring the importance and challenges of global health. Like any learning strategy, it should not be used repeatedly, as this leads to participant saturation and subsequent decline in motivation.

Generally, the strategy's potential is lower with extended texts, whereas it demonstrates substantial benefits when applied to images, videos, short texts, or real-world cases.

## Activity assessment

If the objective is to review the statements produced by participants and assign a grade, the following checklist is proposed, as shown in Table 3.

**Table 3**

*Checklist. Constructed to assess five statements (I Notice) and their corresponding questions (I Wonder)*

| Criterio | Total score | Score achieved (per exercise and total) | | | | |
|---|---|---|---|---|---|---|
| **A. *I notice*** | | | | | | |
| | Exercise: | 1 | 2 | 3 | 4 | 5 |
| • It is based on the given case study or reading. | 5 | | | | | |
| • It is not based on the case, it is a personal interpretation, opinion or other approach derived from another context. | 1-4 | | | | | |
| • The writing is forceful, clear, and precise. | 5 | | | | | |
| • The writing shows ambiguities or inaccuracies. | 1-4 | | | | | |
| Subtotal | | | | | | |
| **B. *I wonder*** | | | | | | |
| | Exercise: | 1 | 2 | 3 | 4 | 5 |
| • The question is clearly stated. | 10 | | | | | |
| • The question is unclear/confusing. | 5-8 | | | | | |
| • Question emerges from the context, case study or reading. | 10 | | | | | |
| • Question does not stem from observation of the context or case study. | 5 | | | | | |
| • Questions reveal deep analysis or are formulated as problematic cores (question sets addressing a single problem). | 5-10 | | | | | |
| • Questions demonstrate simplistic construction, forced formulation, or obvious answers. | 1-5 | | | | | |
| Subtotal | | | | | | |
| **C. The relation between *I notice* and *I wonder*** | | | | | | |
| | Exercise: | 1 | 2 | 3 | 4 | 5 |
| • They demonstrate mutual coherence. | 20 | | | | | |
| • No correspondence exists between observation and question. | 5 | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Subtotal | | | | | |
| **D. Sufficiency of the approaches** | | | | | | |
| | Exercise: | 1 | 2 | 3 | 4 | 5 |
| • A minimum of five In-Iw approaches were carried out. | 20 | | | | | |
| • Fewer than three statements were produced. | 5-19 | | | | | |
| • The entire reading or context was taken into consideration. | 20 | | | | | |
| • Statements were constructed using only a portion of the reading or context under study. | 5-19 | | | | | |
| **Total score** | **100** | | | | | |
| **Comments:** | | | | | | |

### *Evaluation of the strategy by students*

Four primary categories concerning the educational value of the technique are identified in the metacognitive reflections expressed within student learning journals: the importance and perception of the activity, "dialoguing with the author" (dialogue exercise), advantages of engaging with "I Notice" and "I Wonder" and alternatives for overcoming rigid reading. Illustrative testimonies from participants are presented below:

> "Today we conducted the group review of the co-evaluations of the 'I notice, I wonder' activity, and I realized how interesting this activity was for me. I learned to be more specific and clearer with my ideas when formulating statements and questions, while simultaneously understanding the importance of establishing coherence between these elements within the work. [...] Regarding the article, I realized that we need to carefully select the ideas we take from it to better understand the reading".

> "The exercise serves as a form of dialogue with the author of the article, where we can pose new questions that encourage further research, by identifying key points that are complemented and integrating them with knowledge we already had from previous readings, the analysis becomes even more complete".

> "The reading becomes more condensed and easier to comprehend, since the technique itself makes it simpler for the reader"

> "In this activity I learned to reflect more deeply on my reading, to move away from such rigid reading and adopt a more reflective reading, since information is often forgotten when it doesn't pass through that mental filter. Furthermore, all information

leaves us with something newly learned, and we will only recognize this when we engage in philosophical and argumentative thinking about the topic".

"This was truly an exercise that facilitated the reinforcement of knowledge gained from the article and improved our writing and question-generation abilities. I personally valued the activity because it facilitated the reinforcement of knit, which permitted me to perceive the article from another perspective, as the statements and questions of the classmate assigned to me for evaluation diverged from my own, allowing me to become aware of aspects I had initially overlooked".

"During the "I notice, I wonder" activity, I pondered whether implementing a public policy to restrict electronic device use would be advantageous [...], since health issues resulting from excessive electronic device usage affecting multiple organ systems have emerged recently. However, it's important to consider that new technology also provides benefits. This leads me to conclude that the activity represents an outstanding reflective exercise that not only enhances our understanding of the reading but also encourages us to examine the relevance of the information and even relate it to our personal perspectives".

## DISCUSSION AND CONCLUSIONS

Confronting a different way of addressing problems and learning is probably the most significant obstacle to engaging with the *I Notice, I Wonder* strategy; this difficulty is observed not only in students but also in teachers. In this regard, we concur with Watson's (2002, p. 117-120) work, who concludes by stating the following:

> I realized that others often struggle to notice. Students enter school far too frequently, holding the belief that "correct answers" exist and that possibilities for responding to coursework are limited. They show resistance to use the first-person perspective in essays, [...] and lack trust in their reactions to practical experiences [...].

Through this work, we have identified a certain intellectual conditioning with respect to how problems are conceptualized, and new knowledge is acquired, notably, we have observed that in medical education, despite the introduction of new pedagogical frameworks, a positivist orientation toward content persists and, as we previously noted, problem-solving approaches are characteristically formulated, in first approximation from clinical logic: *causation, diagnosis,* and *therapeutic intervention*.

Aligning with this challenge, Witt, Onorato, and Schwartzstein (2022) have observed the particular tendency in medical students to increasingly request a "response key" for all aspects of their education. Students routinely anticipate having correct answers immediately available to ensure their conclusions are accurate and to determine precisely what knowledge they need to master. Although much

of medical practice, particularly in the care of critically ill patients with multisystemic diseases in intensive care units, the answers are uncertain and the body of knowledge is growing more and more. Student's demands for single solutions pose a threat to their development as self-reliant, critical-thinking physicians. In line with our observations, the trend identified by Witt, Onorato, and Schwartzstein (2022) may find part of its origin in the imperious hierarchy ascribed to grades and examinations throughout the different stages of their formation.

Given the above issues, it is necessary to develop strategies that promote critical judgment. Similarly, problematization stands as a fundamental intellectual exercise not only for global health, but for all sciences and disciplines. Since questions are starting point of research, the *I Notice, I Wonder* strategy could be utilized in various educational settings.

Regarding the nature of questions, it is important for the professor to identify their complexity, since this allows us to gain insight into student's thinking, their academic and personal concerns, and the cognitive skills they put into play. At least three types of questions could be considered: *Confirmative* (to refine understanding), *Clarifying* (to resolve uncertainty), and *Challenging* (to address problematic situations). Nonetheless, "we have observed" during initial *I Notice, I Wonder* practice that questions often formulated by paraphrasing what has been noticed, becoming questions when "why" or "how could one..." is appended. This implies initial questions are characteristically grounded in superficial or limited observation and may contain implicit value judgments. The quality and depth of questions, however, improve in later exercises, with increasing prevalence of those advancing provocative ideas or presenting intellectual challenges (termed *challenging questions* earlier).

On a different but equally important point regarding question-posing. Wolbert and Schinkel (2020) argue that questioning serves educational significance beyond motivating learning, it is fundamentally important because it represents an integral aspect of learning to comprehend the difference between "what you don't know, what you merely believe you know, and what you (as human being) cannot know or understand". We might further observe that analysis of student-posed questions could facilitate teachers' identification of students' learning needs.

At the operational level, in order to obtain greater educational benefits from the *I Notice, I Wonder* strategy, it is necessary to practice the process several times, review the approaches and feedback the work of the participants.

It is also essential that teachers incrementally develop their ability to comprehend and interpret the thinking of activity participants. The *I Notice, I Wonder* strategy facilitates, in some measure, the tangible expression of students' thought processes, something absent in traditional instruction when teachers ask did you understand? and students simply remain silent, respond with a mere "yes" or choose to "analyze" situations through personal opinions or anecdotes.

Finally, designing and adapting approaches for varied learning contexts requires co-construction that teachers engage in the same or similar learning experiences themselves. It also demands reflective practice grounded in student learning outcomes and one's own metacognitive processes. In essence, innovation in the classroom extends beyond merely applying techniques, an *instrumental understanding of teaching*, to encompass the development of genuine pedagogical thought.

This study presents practical classroom experience, describing an initiative that indisputably contributes to the improvement of the student learning process in "Global Health" courses and, although with some caveats, in the pedagogical training of medical faculty.

We consider the *I Notice, I Wonder* experience presented here innovative based on the three factors: a) It originates from Anglo-Saxon educational traditions, with no prior Spanish or Portuguese scholarship identified; b) Unlike reviwed studies, its application targets advanced cognitive outcomes, specially the development of problematization skills, fundamental to scientific training; c) It introduces an original evaluation checklist for assessing the appropriateness of observations (*Noticing*) and a framework for analyzing the nature and complexity of questions generated (*Wondering*).[1]

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# Educational Policy in Mexico: Analysis of Civic Education in the State of Puebla

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*— Abstract—*

This paper aims to show the main advances that Civic Education has had in the state of Puebla, after the review and analysis of the different educational reforms that have taken place throughout the history of Mexico, taking into consideration the responsibility of the state to ensure the civic education of new Mexican citizens. The main objective of the research process was to establish the concept of Civic Education in a documentary sample. The methodology used was the implementation of a closed survey by convenience sampling applied to 5 boys and 5 girls from 4 school belonging to the municipalities of Huejotzingo, Libres, Puebla and Teziutlán in the state of Puebla. Among the conclusions, it is highlighted that the advances in civic education are significant in the four municipalities, although the municipality of Huejotzingo stands out as the one that has solid knowledge in students regarding what civic education means.

**Keywords:**

*Civic education; educational reform; personal data; transparency; right to know and civic values.*

Throughout the history of the Mexican government, there has been a constant stream of educational reforms established as public policies, all aimed at improving educational quality and equity in the nation. While such reforms have occurred throughout the country's history, they have become increasingly frequent in recent decades.

The objective of this article is to analyze 3 main pillars that have constituted the foundation for transparency-based educational policy proposed in Mexico. The article is therefore organized into 3 sections: the first seeks to establish a brief history about the policies promoted in Mexico during each six-year period; the second presents a perspective on Mexico's latest educational reform; and their third concludes with presentation of the researcher's sample analysis to determine progress of the transparency-based educational policy initiative in four municipalities of the Puebla State.

Therefore, Mexican educational reforms throughout the nation's history can be enumerated beginning in the nineteenth century, during Benito Juárez administration, who established the foundation of the essence of public education under the mandate of state responsibility to provide it publicly and without cost. However, it is important to notice that given the resource constraints and political opposition of that historical period, this reform achieved little impact (Villalvazo Ruiz, 2016).

The twentieth century witnessed intensified governmental implementation of educational reforms, motivated by the necessity to address economic and social demands confronting the nation as a result of historical development. In 1921, the government under Álvaro Obregón founded the institution that remains operative and continues fulfilling educational demands today.

In reference to the Secretariat of Public Education of Mexico (Secretaría de Educación Pública, SEP), whose responsibility is the formulation and coordination of public education programs addressing the population's needs (Villalvazo Ruiz, 2016).

Throughout the 1980s and 1990s, governmental educational reforms focused on modernization and decentralization of the educational system. Under the Carlos Salinas de Gortari administration, an education modernization program was instituted seeking to enhance educational system efficiency and effectiveness through decentralized school management and integration of new educational technologies (Villalvazo Ruiz, 2016).

Since the beginning of the twenty-first century, educational reform-focused public policies have prioritized quality and equity improvements in education. The 2013 educational reforms presented by Enrique Peña Nieto emphasized teacher evaluation processes as instruments for securing educational advancement while incorporating curricular renewal and autonomous school management (Villalvazo Ruiz, 2016).

Public policies centered on educational reform have significantly impacted the development of Mexico's educational system, making possible the expansion of educational coverage, the improvement of basic education levels, and the strengthening of school autonomy.

The Educational Reform pursues the following fundamental objectives:

- Responding to a social demand to strengthen public, secular, and free education (Gobierno de la República, 2023).
- Ensure greater equity in access to quality education (Gobierno de la República, 2023).
- Strengthen the school's management capacities (Gobierno de la República, 2023).
- Establish a professional teaching service with rules that respect the labor teacher's rights. (Gobierno de la República, 2023).
- Promote new opportunities for the professional development of teachers and executives (Gobierno de la República, 2023).
- Lay the foundations for the elements of the Educational System to be evaluated impartially, objectively, and transparently (Gobierno de la República, 2023).

These objectives will be translated into concrete benefits for Mexicans:

- A substantial improvement in the quality of education (Gobierno de la República, 2023).
- Strengthening free public education (Gobierno de la República, 2023).
- Schools strengthened and supported as central to fundamental decision-making (Gobierno de la República, 2023).
- An evaluation framework grounded in merit and acknowledgement of teaching vocation (Gobierno de la República, 2023).
- Inclusive education within reach of all citizens (Gobierno de la República, 2023).
- Appropriate utilization of public resources (Gobierno de la República, 2023).

It is essential to note, however, that Mexican educational reforms have been and continue to be contested and controversial. Major criticisms hold that these reforms have been excessively radical, leading to direct teacher opposition. Other viewpoints argue that these reforms have not genuinely achieved their intended effects, failing to produce real improvements in educational quality.

One of the main challenges that arise in Mexico is the establishment of a public policy focused on the civic education of the citizen, since this has as an integral approach the requirement that combines the formation of knowledge, skills and values in Mexican society.

Given these considerations, it is essential to clearly understand how civic education would be articulated in the following areas:

- **Knowledge development**: which should emphasize students' development of basic understanding regarding their rights, obligations, duties, and responsibilities as citizens. This includes knowledge of democratic society's principles and values to facilitate participation through civic engagement mechanisms (Caballero Álvarez, 2016).
- **Skills development**: this focused on students acquiring critical analysis skills, problem solving, and conscious decision making in democratic processes. The aim is to develop the ability to communicate effectively and work collaboratively for the development of the nation (Caballero Álvarez, 2016).
- **Values development**: centered on students' responsibility to develop democratic commitment extending to social justice and equality obligations. Through this, students could develop civic responsibility and commitment to active citizenship. (Caballero Álvarez, 2016).

Although to achieve the above it is necessary to consider the challenges that civic education will face in Mexico, which can be considered in the following axes:

- **Resistance to change**: it is important to consider how different educational and social actors may become an obstacle when proposing transformation processes that improve quality of life, in this case the proposal of civic education for Mexican society (Executive Directorate of Electoral Training and Civic Education [Dirección Ejecutiva de Capacitación Electoral y Educación Cívica], 2011).
- **Complexity of change**: the proposal of a public policy focused on civic education in Mexico is observed as a complex issue that will require a comprehensive approach process. This is necessary to consider how it will be implemented in the nation's educational model (Executive Directorate of Electoral Training and Civic Education, 2011)
- **Lack of resources:** taking into consideration that every transformation process requires practical action, civic education in Mexico would require not only the work of teachers but also a series of specialists in the field who would propose the construction of the curriculum. This, of course, establishes the limitation of time and available resources to achieve it (Executive Directorate of Electoral Training and Civic Education, 2011).

Although the proposal of a public policy focused on the integration of civic and social education will have to emanate from the government, it could not face the challenge of reaching a successful conclusion on its own. Therefore, it is necessary to coordinate efforts among schools, families, and society in general if this objective is to be achieved.

Considering that by approaching it in this manner, it would have to be considered that it must be centered on:

- **Development of educational materials**: the task will be to update educational materials and create a subject specialization in the proposed civic and social education (Executive Directorate of Electoral Training and Civic Education, 2011).
- **Update of teacher training**: training will be needed for teachers who can teach the civic education subject efficiently (Executive Directorate of Electoral Training and Civic Education, 2011).
- **Promoting citizen participation**: for civic and social education to present results, these would have to be observed to the extent that students become actively involved in participating in social activities in their public environment (Executive Directorate of Electoral Training and Civic Education, 2011).

It is important to consider that the proposal of a civic and social education that has an impact on the development of Mexican citizens is a future proposal that has as its intention or pretense the formation of civil society with active citizen participation.

The following research is presented with the aim of analyzing the relationship between the promotion of civic education (Dewey, 1998; Durkheim, 2013) by the Mexican government and the level of knowledge on these issues of students from selected schools in Puebla, Mexico. The program implemented by the Mexican government in the areas of civic education will be analyzed. Likewise, the level of knowledge that students have in these areas in schools will be identified.

In general, the research variables would be related to the promotion of civic education by the Mexican government and the level of knowledge on these topics among selected schools in Mexico. Some specific possible variables that were considered include:

- Promotion of civic education by the Mexican government (independent variable).
- Level of knowledge in education, and civic education among students (dependent variable).
- Policies and programs for civic education implemented by the Mexican government (independent variable).

The scope of the research will be exploratory in nature, limited to selected schools in the state of Puebla, Mexico, which would allow obtaining detailed and specific information on the level of knowledge in early education, civic education of students in said schools. In addition, the research would focus on the

descriptive process of the analysis of the policies and programs implemented by the Mexican government to promote civic education.

This research is basically the result of a survey on the knowledge of fourth-grade elementary school students in the state of Puebla. The questionnaire used, reproduced at the end of this study, draws on works such as *La Politización del niño Mexicano* [The Politicization of Mexican Children] (Segovia, 2014) and *Mejores prácticas de transparencia, índice de percepción de corrupción en niños* [Best Practices in Transparency, Corruption Perception Index in Children] (Sánchez Zamora, 2015).

This questionnaire contains variables such as Ledo, limitations mentioned supra, in referring to the hypothetical phenomena that will be divided depending to a simple equation, either "civic values"; "rights and obligations"; "personal data protection"; "right to know"; or "transparency". Each of the aforementioned sections will, in turn, analyze four concepts, which were taken from the *Civic and Ethical Education* books for all primary school grades, published by the SEP in 2022.

To evaluate the relationship between the Mexican government's promotion of transparency education and civic education and students' level of knowledge on these topics in selected schools in Puebla, Mexico.

## MATERIALS AND METHODS

The purpose of the research on the implementation of transparency education as a component of civic education is to analyze the degree of applicability and success in training future citizens who will participate in the experimental process.

It was applied to 40 girls and 40 boys who were in the fourth grade of primary school in the aforementioned municipalities, in 4 municipalities of the State of Puebla such as: Puebla Capital, Huejotzingo, Libres and Teziutlán.

In general, the research variables would be related to the promotion of civic education by the Mexican government and the level of knowledge on these issues among students from selected schools in Mexico. Some possible specific variables that are being considered include:

- Promotion of civic education by the Mexican government (independent variable).
- Level of knowledge in civic education among students (dependent variable).
- Policies and programs for civic education implemented by the Mexican government (independent variable).

## RESULTS

Considering the four municipalities that were evaluated: In Huejotzingo, with boys and girls attending "Centro Escolar Profesor Enrique Martínez Márquez" [Professor Enrique Martínez Márquez School Center]; Libres, including boys and girls attending "Primaria del Centro Escolar Miguel Cástulo De Alatriste" [Miguel Cástulo De Alatriste School Center Primary School]; Puebla, including boys and girls attending "Primaria Instituto Francisco Esqueda" [Francisco Esqueda Institute Primary School]; and Teziutlán including boys and girls attending "Primaria Centro Escolar Presidente Manuel Ávila Camacho" [President Manuel Ávila Camacho School Center Primary School]. The following results were obtained:

For data collection, a total of five 9-year-old boys and 9-year-old girls were selected as the sample. The concepts expressed by the groups were scored on a scale from 0 to 4, with 0 representing the least probable outcome and 4 representing the optimal outcome. Five simple equations were established for the experiment, corresponding to the following categories:

**Table 1**

*Simple equation on personal data protection*

| SIMPLE EQUATION ON PERSONAL DATA PROTECTION | | | | |
|---|---|---|---|---|
| Variables | Variables | Hypothetical Phenomenon | | |
| (BIO) | Family | w | Identity | A |
| | School | x | Identifiable | B |
| | Friends | y | Name | C |
| | Media | z | Image | D |

It is important to note that the hypothetical phenomena were derived from the study of the SEP first-grade primary textbooks on Civic and Ethical Education from 2022, in which the aforementioned source references several concepts closely related to those under study, such as the right to identity (*personal data full name, date of birth, gender, place of birth and nationality*), as well as the recognition of some of the most fundamental human rights (life, recreation, leisure, identity, family, nutrition, protection, housing, education, participation, freedom of expression, and health) (Jiménez Ramírez & Juárez Herrera, 2022).

Therefore, the following question was asked: What is the degree of information that the students of fourth grade of primary schools of the selected schools of the state of Puebla have about the protection of personal data?


***Figure 1.*** Correlation analysis of knowledge level

## Table 2

*Correlation coefficient of knowledge level*

| | **Municipality** | **Knowledge** |
|---|---|---|
| Municipality | 1 | |
| Knowledge | 0.42977398 | 1 |

***Note.*** This table presents the interview conducted by the researcher with 5 girls and 5 boys aged 9 years old from the municipalities of: Huejotzingo, with boys and girls attending Primaria Centro Escolar Professor Enrique Martínez Márquez; Libres, including boys and girls attending Primaria Centro Escolar Miguel Cástulo de Alatriste; Puebla, including boys and girls attending Primaria Instituto Francisco Esqueda; and Teziutlán, including boys and girls attending Primaria Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

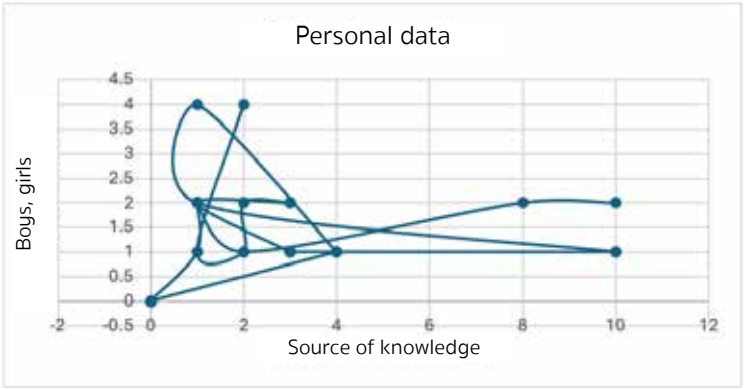


***Figure 2.*** Correlation analysis of source of knowledge

## Table 3

*Correlation coefficient for source of knowledge*

| | **Children** | **Source** |
|---|---|---|
| Children | 1 | |
| Source | 0.16682952 | 1 |

***Note.*** Interview conducted by the researcher with 5 girls and 6 boys aged 9 years from the municipalities of: Huejotzingo, with boys and girls attending Primaria Centro Escolar Professor Enrique Martínez Márquez; Libres, including boys and girls attending Primaria Centro Escolar Miguel Cástulo de Alatriste; Puebla, including boys and girls attending Primaria Instituto Francisco Esqueda; and Teziutlán, including boys and girls attending Primaria Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

**Table 4**
*Simple equation on the right to know*

| SIMPLE EQUATION ON THE RIGHT TO KNOW | | | | |
|---|---|---|---|---|
| Variables | Variables | Hypothetical Phenomenon | | |
| (BIO) | Family | w | Information | A |
| | School | x | To Ask | B |
| | Friends | y | To Know | C |
| | Media | z | Authorities | D |

It is important to note that the hypothetical phenomena were derived from the study of the SEP textbooks on Civic and Ethical Education (2022), the concept of information and authorities; on the other hand, the concepts of asking and learning came from the third-grade textbooks. Additionally, with reference to the second-grade textbook, regarding the "rules for harmonious coexistence" (Benlliure Bilbao, 2022) whose competence is: adherence to legality and sense of justice, understanding and appreciation for democracy, we examined what corresponds to "freedom of expression which is the right we are analyzing", therefore all children have the right to say what they think and feel, and it is recognized that each one has their own ideas and can change their opinion (Benlliure Bilbao, 2022).

Therefore, the following question was asked: What is the level of knowledge that fourth-grade students from the selected primary schools in the state of Puebla have regarding THE RIGHT TO KNOW?


***Figure 3.*** Correlation analysis of knowledge level

**Table 5**

*Correlation coefficient of knowledge level*

| | Municipality | Knowledge |
|---|---|---|
| Municipality | 1 | |
| Knowledge | 0.09416215 | 1 |

***Note.*** Interview conducted by the researcher with five 9-year-old boys and five 9-year-old girls from the municipalities of: Huejotzingo, with boys and girls who study at Primaria Centro Escolar Profesor Enrique Martínez Márquez; Libres, with boys and girls who study at Primaria del Centro Escolar Miguel Cástulo De Alatriste ; Puebla, with children studying at Primaria Instituto Francisco Esqueda; and Teziutlán, with children studying at Primaria Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

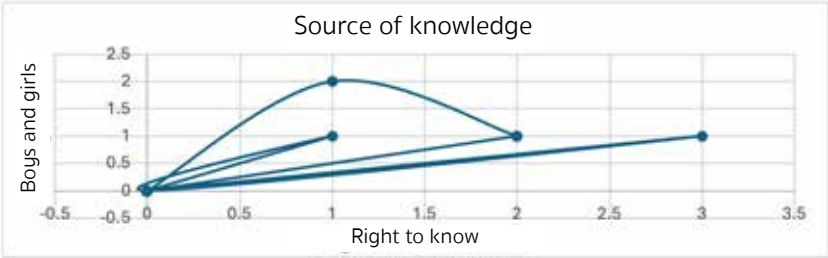


***Figure 4.*** Correlation analysis of source of knowledge

**Table 6**

*Correlation coefficient for source of knowledge*

| | Children | Source |
|---|---|---|
| Children | 1 | |
| Source | 0.16682952 | 1 |

***Note.*** Interview conducted by the researcher with five 9-year-old boys and five 9-year-old girls from the municipalities of: Huejotzingo, with boys and girls who study at Centro Escolar Profesor Enrique Martínez Márquez; Libres, with boys and girls attending Centro Escolar Miguel Cástulo de Alatriste; Puebla, with boys and girls attending Instituto Francisco Esqueda; and Teziutlán, with boys and girls who study at Primaria Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

**Table 7**

*Simple equation for rights and obligations*

| SIMPLE EQUATION ON RIGHTS AND OBLIGATIONS | | | | |
|---|---|---|---|---|
| Variables | Variables | Hypothetical phenomena | | |
| (BIO) | Family | w | Family | A |
| | School | x | Life | B |
| | Friends | y | Health | C |
| | Media | z | Education | D |

It is important to mention that the hypothetical phenomena were obtained from the study of SEP textbooks, from first to sixth grade of primary school, on Civic and Ethical Education (2022). Now then, with reference to the fourth-grade textbook, regarding Block 1, entitled "I decide with freedom and responsibility", it recognized that people have dignity and the capacity to exercise their rights through human rights established to protect each person and, thereby, ensure that everyone lives fully. Some of the rights mentioned include: "living as family", "living a life free from violence", "education", "equality", "life, liberty", and "security", "rest and recreation", and "participation" (Chao Rebolledo, Jiménez Muñoz Ledo, Gómez Neri & Romo Pimentel, 2022).

Therefore, the following question was raised: What is the level of knowledge that fourth-grade primary school students from selected schools in the state of Puebla have regarding RIGHTS AND OBLIGATIONS?

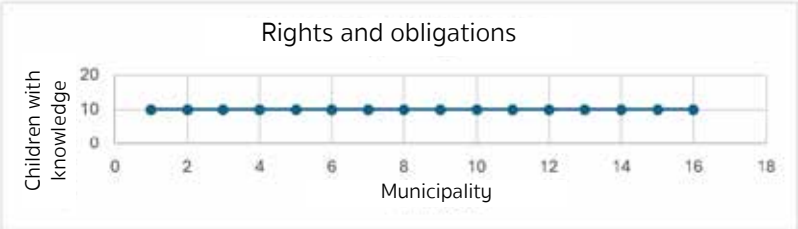


***Figure 5.*** Correlation analysis of the level of knowledge

**Table 8**

*Correlation coefficient of the degree of knowledge*

| | **Municipality** | **Knowledge** |
|---|---|---|
| Municipality | 1 | |
| Knowledge | 0.99999999 | 1 |

***Note.*** Interview conducted by the researcher with five 9-year-old boys and five 9-year-old girls from the municipalities of: Huejotzingo, with boys and girls who study at Centro Escolar Profesor Enrique Martínez Márquez primary school; Libres, with boys and girls attending Centro Escolar Miguel Cástulo de Alatriste; Puebla, with boys and girls attending Instituto Francisco Esqueda; and Teziutlán, with boys and girls who study at Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

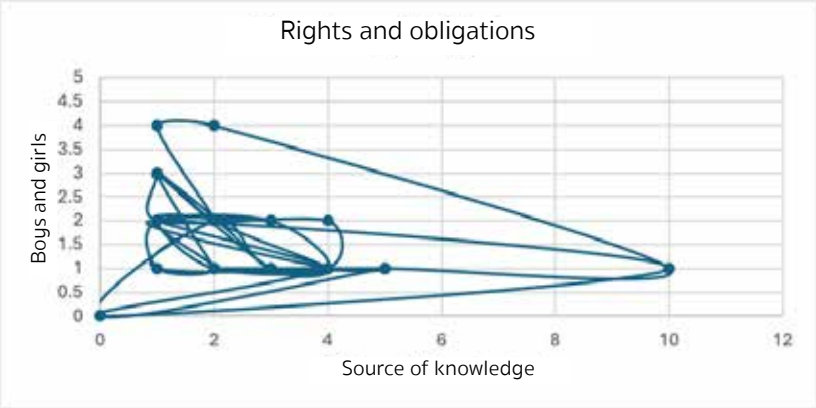


***Figure 6.*** Correlation analysis of the source of knowledge

**Table 9**

*Correlation coefficient of the source of knowledge*

| | Children | Source |
|---|---|---|
| Children | 1 | |
| Source | 0.16682952 | 1 |

***Note.*** Interview conducted by the researcher with five 9-year-old boys and five 9-year-old girls from the municipalities of: Huejotzingo, with boys and girls who study at the Centro Escolar Profesor Enrique Martínez Márquez primary school; Libres, with boys and girls attending Centro Escolar Miguel Cástulo de Alatriste; Puebla, with boys and girls attending Instituto Francisco Esqueda; and Teziutlán, with boys and girls who study at Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

**Table 10**

*Simple equation on transparency*

| SIMPLE EQUATION ON TRANSPARENCY | | | | |
|---|---|---|---|---|
| Variables | Variables | Hypothetical phenomena | | |
| (BIO) | Family | w | Honesty | A |
| | School | x | Advertising | B |
| | Friends | y | Opacity | C |
| | Media | z | Lie | D |

It is important to mention that the hypothetical phenomena were obtained from what the students mentioned during the workshop, since these concepts do not emerge until the fifth-grade Civic and Ethical Education textbook, which only addresses the authorities' obligation to report their actions. Now then, for this to occur, there must be a "culture of legality and honesty among public servants" (Romo Pimentel, Deceano Osorio, & Gómez Neri, 2022), that is, they must demonstrate: reasonableness, with perfect application of the laws, prioritizing society's interests over any personal interest, as well as applying their knowledge

to fulfill their function and report their actions and the resources used to do so. (Romo Pimentel, Deceano Osorio, & Gómez Neri, 2022).

Therefore, the following question was posed: How much do fourth-grade students in selected schools in the state of Puebla know about TRANSPARENCY?

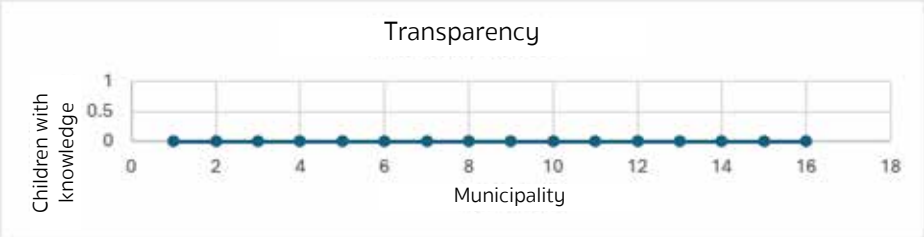


***Figure 7.*** Correlation analysis of the level of knowledge

**Table 11**

*Correlation coefficient for the level of knowledge*

| | **Municipality** | **Knowledge** |
|---|---|---|
| Municipality | 1 | |
| Knowledge | 0.0000000 | 1 |

***Note.*** Interview conducted by the researcher with five 9-year-old boys and five 9-year-old girls from the municipalities of: Huejotzingo, with boys and girls who study at Centro Escolar Profesor Enrique Martínez Márquez; Libres, with boys and girls attending Centro Escolar Miguel Cástulo de Alatriste; Puebla, with boys and girls attending Instituto Francisco Esqueda; and Teziutlán, with boys and girls who study at Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

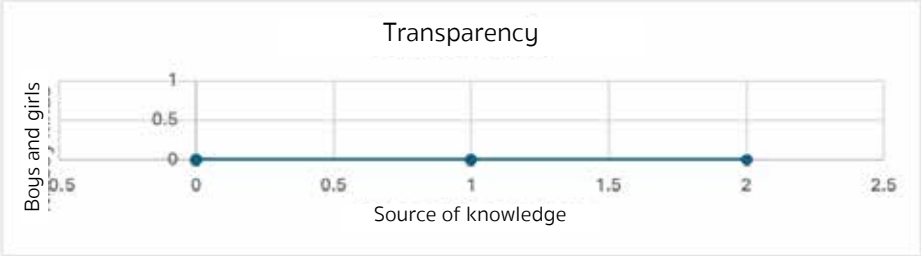


***Figure 8.*** Correlation analysis of the source of knowledge

**Table 12**

*Correlation coefficient of the source of knowledge*

| | Children | Source |
|---|---|---|
| Children | 1 | |
| Source | 0.0000000 | 1 |

***Note.*** Interview conducted by the researcher with five 9-year-old boys and five 9-year-old girls from the municipalities of: Huejotzingo, with boys and girls who study at Centro Escolar Profesor Enrique Martínez Márquez; Libres, with boys and girls attending Centro Escolar Miguel Cástulo de Alatriste; Puebla, with boys and girls attending the Instituto Francisco Esqueda; and Teziutlán, with boys and girls who study at Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

**Table 13**

*Simple equation on civic values*

| SIMPLE EQUATION ON CIVIC VALUES | | | | |
|---|---|---|---|---|
| Variables | Variables | Hypothetical phenomena | | |
| (BIO) | Family | w | Honesty | A |
| | School | x | Respect | B |
| | Friends | y | Justice | C |
| | Media | z | Equity | D |

It is important to mention that the hypothetical phenomena were obtained from the study of the SEP textbooks for grades from first to sixth of elementary school, from Civic and Ethical Education (2022), the concepts of respect and equity; honesty from the fourth to sixth grade textbook, and justice from the second to fourth grade textbook. Now, with reference to the fourth-grade book, regarding block 3, entitled "I act in favor of justice and democracy," it begins by explaining that "justice is necessary to live in democracy and peace," and that the timely, equal, and honest application of laws allows for the protection of people's rights and well-being. To this end, is necessary to understand that "justice means giving everyone their due, caring for and defending their rights and needs, taking into account their personal circumstances" (Chao Rebolledo, Jiménez Muñoz Ledo, Gómez Neri, & Romo Pimentel, 2022).

What is the level of information that students in the fourth grade of primary school in the selected schools in the state of Puebla have about VALUES?

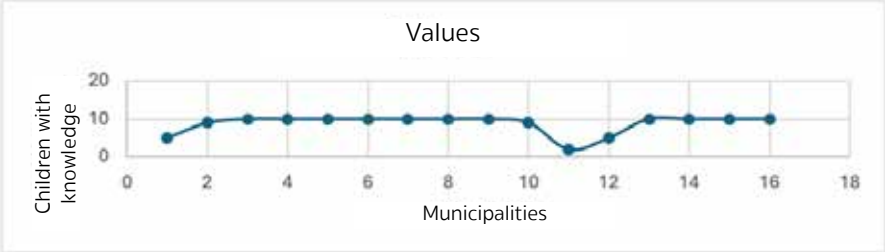


***Figure 9.*** Correlation analysis of the degree of knowledge

**Table 14**

*Correlation coefficient of the level of knowledge*

| | Municipality | Knowledge |
|---|---|---|
| Municipality | 1 | |
| Knowledge | 0.02842561 | 1 |

***Note.*** Interview conducted by the researcher with 5 9-year-old boys and girls from the municipalities of: Huejotzingo, with boys and girls who study at Centro Escolar Profesor Enrique Martínez Márquez; Libres, with boys and girls attending Centro Escolar Miguel Cástulo de Alatriste; Puebla, with boys and girls attending the Instituto Francisco Esqueda; and Teziutlán, with boys and girls who study at Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.


***Figure 10.*** Correlation analysis of the source of knowledge

**Table 15**

*Correlation analysis of the level of knowledge*

| | Children | Source |
|---|---|---|
| Children | 1 | |
| Source | 0.16682952 | 1 |

***Note.*** Interview conducted by the researcher with 5 9-year-old boys and girls from the municipalities of: Huejotzingo, with boys and girls who study at Centro Escolar Profesor Enrique Martínez Márquez; Libres, with boys and girls attending Centro Escolar Miguel Cástulo de Alatriste; Puebla, with boys and girls attending the Instituto Francisco Esqueda; and Teziutlán, with boys and girls who study at Centro Escolar Presidente Manuel Ávila Camacho. From December 5 to 13, 2022.

## CONCLUSION

Once the process of interviews with 9-year-old girls and boys studying in the municipalities of Huejotzingo, Libres, Puebla, and Teziutlán has been completed, it can be pointed out that educational policy still has a long way to go to ensure that knowledge regarding civic and citizenship education is based on the educational process.

### *Results on the level of knowledge*

Regarding the assessment of children's knowledge about personal data protection, comparative data analysis across municipalities indicates that Huejotzingo has experienced deterioration in knowledge reinforcement, Libres has not yet succeeded in developing student knowledge, while Puebla and Teziutlán have made significant gains, achieving optimal knowledge development.

This is reflected in a positive correlation coefficient of 0.429, it can be established that the development trend is aimed at increasing knowledge of "personal data".

The analysis of students' knowledge of the "right to know", a comparative data analysis across municipalities indicates that Huejotzingo has been unable to develop such knowledge, Libres exhibited substantial early gains but failed to sustain them and subsequently declined, preventing knowledge consolidation, a pattern mirrored in Puebla, while Teziutlán has similarly failed to develop this knowledge.

This is reflected in a positive correlation coefficient measurement that, although it is still low at just 0.094, it can be established that the development trend is uncertain. Nonetheless, some progress has been made, setbacks have been more significant.

With respect to the students' knowledge of their "rights and obligations", a correlation of data analysis can be established in the four municipalities: Huejotzingo, Libres, Puebla and Teziutlán have achieved an optimal level of knowledge in students.

This is reflected in a high positive correlation coefficient of 0.999, demonstrating a well-established development trend and confirming that students have achieved a solid understanding of their rights and obligations.

The analysis of students' knowledge of transparency can be established in the four municipalities: Huejotzingo, Libres, Puebla and Teziutlán have not managed to develop knowledge in students and are in a situation where there is little understanding of what it means.

This is reflected in a neutral correlation coefficient of 0.000, it can be established that the development trend is not yet defined, which means that it is open to both possibilities: it is possible to develop and strengthen it as well as there is a risk of not achieving it and that students are left without it.

Regarding the questioning of the knowledge that children have of their "civic values", a correlation of data analysis can be established in the four municipalities:

Huejotzingo, Libres, Puebla and Teziutlán have achieved an optimal level of knowledge in students, although in the case of Puebla there was a significant drop.

This translates into a measurement of a positive correlation coefficient of 0.028 that can be established that the development trend is being strengthened, demonstrating that children can achieve the fullness of knowing their civic values.

*Results on the source of knowledge*

Regarding the questioning of the source of knowledge that girls and boys have of the protection of their personal data, a correlation of data analysis can be established in the municipalities in which it is observed that Huejotzingo has as a basis the learning of knowledge to the family followed by school; Libres does not have a source of knowledge that supports it; Puebla and Teziutlán have made significant progress, achieving optimal knowledge development.

This translates into a positive correlation coefficient measurement of 0.16682952, establishing that the development trend is aimed at increasing knowledge of "personal data".

Respecting the questioning of the source of knowledge that children have of the "right to know", a correlation of data analysis can be established in the municipalities in which it is observed that Huejotzingo does not have an source of knowledge that supports it; Libres has very low levels mainly in the family, education, as happened in the case of Puebla; for its part, Teziutlán does not have an source of knowledge that supports it.

This translates into a positive correlation coefficient measurement that, although it is still low at just 0.16682, it can be established that the development trend is uncertain, since, although some progress has been made, the setbacks have been more significant.

In respect of the questioning of the source of knowledge that children have of their "rights and obligations", a correlation of data analysis can be established in the four municipalities: Huejotzingo, Libres, Puebla and Teziutlán have managed to have solid source relying mainly on the family, followed by education and in some cases friends.

This translates into a high positive correlation coefficient of 0.1668, indicating that the development trend is entrenched and that children are fully aware of their rights and obligations.

Regarding the questioning of the source of the knowledge that children have of transparency, a correlation of data analysis can be established in the four municipalities: Huejotzingo, Libres, Puebla, and Teziutlán. There is no source of knowledge in the students, and they are in a situation devoid of what it means.

This translates into a measurement of a neutral correlation of 0.000, that can be established that the development trend is not yet defined, which means that it is

open to both possibilities: it is possible to develop and strengthen, as well as there is a risk of not achieving it, and that students are left without it.

Respecting the questioning of the source of knowledge that children have of their "civic values", a correlation of data analysis can be established in the four municipalities: Huejotzingo, Libres, Puebla, and Teziutlán have managed to establish a solid foundation based mainly on the family, followed by education and, in some cases friends.

This translates into a positive correlation coefficient measurement of 0.1668, which indicates that the development trend is strengthening, demonstrating that children can achieve the fullness of knowing their civic values.

Although, as can be seen from the data obtained in the experiment, the main source of civic education for primary school children in the different municipalities of the state of Puebla is still in the hands of the family. It can be seen that there is significant progress in the educational policies implemented by the government, which seek to establish a process in which the training of citizens is based on a democratic model based on public transparency and accountability.

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# Synthesis of Zinc Oxide by the hydrothermal method: effect of aging time

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*— Abstract—*

Nanomaterials have many applications, including in health, the environment, energy, and electronics. Their performance in these areas depends on specific optical, morphological, and physical properties, which are determined by how they are prepared. Factors such as reaction temperature, solution pH, precursor concentration, type of solvent, stirring rate, and aging time are currently studied. The objective of this work is to study the effect of aging time on particle formation at different durations: 24 h, 12 h, and without aging, at two pH values, 7 and 9. The synthesis was done using the hydrothermal method, with zinc chloride ($ZnCl_2$) and ammonium hydroxide ($NH_4OH$) as precursors. The samples were characterized by X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and Ultraviolet-Visible Spectroscopy (UV-Vis). At pH 7, the samples mainly formed ZnO, with stronger and sharper peaks after 24 hours of aging. At pH 9, aging promoted the formation of the simonkolleite phase. In both cases, particle size increased with aging time, reaching about 40 nm for pH 7 and 36 nm for pH 9. The band gaps were 3.20 eV for ZnO and 3.24 eV for simonkolleite. It was found that pH plays an important role in phase formation and, together with aging time, affects the morphology of the materials.

**Keywords:**

*ZnO, simonkolleite, nanoparticles, hydrothermal method.*

Nanotechnology is one of the research fields that has gained the most attention in recent years, as the development of new materials at nanometric scales <100 nm promotes emerging technology in the transition toward more environmentally friendly energy models. Nanomaterials display physical and chemical properties different from macroscopic-sized materials, primarily because they possess greater specific surface area per unit volume (Echeverri et al., 2021). The interest in nanomaterial development is highlighted due to its substantial growth; enhanced understanding of the relationship between properties and structures is anticipated, along with progress in manufacturing techniques facilitating their applications across various fields, including medicine, optics, electronics, textiles, cosmetics, catalysis, and energy (Malaret et al., 2023).

ZnO nanoparticles are distinguished by their stable structure; their non-toxic nature features a wide bandgap of 3.37 eV and exciton binding energy of 60 meV (Widiyandari et al., 2023). Maintaining competitiveness with other materials requires improving synthesis methods for high-quality, low-cost production (Guzmán et al., 2022). This metal oxide is produced via diverse physical and chemical methods. Amongdifferent synthesis routes, the hydrothermal approach is particularly notable for being eco-friendly, economical, straightforward, and easily controllable. Additionally, nanoparticles obtained by this method demonstrate high crystallinity relative to those produced through other solution-based processes (Sansenya et al., 2021).

Studies such as that of Pittayathorn et al. (2023), which examined the beneficial impact of ZnO aging, attributed this to increased oxygen vacancy formation in the material. These findings highlight the importance of investigating factors including aging and pH modification in ZnO and simonkolleite formation, motivating this study focused on understanding their effects on crystal structure, morphology, and other relevant material properties. Adjusting synthesis parameters in these methods enables tailoring material properties to specific industrial application requirements, ensuring reproducibility, efficiency, and scalability (Guzmán et al., 2022).

## MATERIALS AND METHODS

Synthesis employed the hydrothermal method. A 0.1 mol/L ZnCl2 solution in 0.1 L H 2O was prepared and continuously stirred on a thermomagnetic stirrer (Thermo Scientific) for 30 min at room temperature. The pH was adjusted to 7 and 9 by slowly adding 1 mol/L NH 4OH dropwise. The mixture underwent three aging conditions: 24, 12, and 0 h, with the latter serving as an unaged control. All treatments were conducted in darkness at room temperature. Each solution was then transferred to a stainless-steel autoclave reactor (17.48x5x5 cm) and heated to 200 °C for 180 min in a convection oven (Binder model). The mixture underwent gravity filtration, and the remaining solution was centrifuged at 3500 rpm (≈1500g) for 15 min using a centrifuge (MPW 223e). The precipitate was washed twice with

water and methanol, dried on a thermomagnetic stirrer (Thermo Scientific), and ultimately calcined at 400 °C for 240 min in a muffle furnace (Felisa-341).

### *Characterization*

Sample crystal structure was determined via X-Ray Diffraction (XRD) on a Rigaku Ultima IV diffractometer, utilizing Cu Kα radiation with λ=1.5418×10−10 or 1.5418 Å, 2θ/θ scan angle, scan speed of 2°per minute, and scan range of 20° to 80°. Operating conditions included 40 kV voltage, 44 mA current, and Bragg-Brentano geometry. Morphology was examined by Scanning Electron Microscopy (SEM) using Hitachi FE-SEM S-5500 equipment at various magnifications. Diffuse reflectance spectroscopy (DRS) was performed on a Shimadzu UV-Vis-NIR-3600 spectrophotometer equipped with an integrating sphere across the 200 to 800 nm range.

Crystal size was determined by the Scherrer equation corresponding to equation (1).

$$L = \frac{k\lambda}{FWHM \cos\theta} \qquad \text{(Equation 1)}$$

Where: ***k*** represents the Scherrer constant valued at 0.89, λ denotes Cu Kα radiation wavelength, FWHM (Full Width at Half Maximum) indicates the (hkl) peak half-width, and θ designates the angular position of XRD peaks, half of 2θ.

Bandgap (*Eg*) calculations employed two formulas: the Kubelka-Munk equation, equation (2), and the Tauc equation, equation (3).

$$R = \frac{(1-R)^2}{2R} \qquad \text{(Equation 2)}$$

$$\alpha h\nu = A\left(h\nu - E_g\right)^n \qquad \text{(Equation 3)}$$

Where R represents the experimentally measured diffuse reflectance, α denotes the material's absorption coefficient, hv indicates the indicent photon energy (eV), A is a proportionality constant, and "n" corresponds to the electronic transition exponent-in this case $^1/_2$ according to Hedge et al. (2024) attributed to the direct transition nature in ZnO and crystalline Simonkolleite solid ($Zn_5(OH)_8Cl_2 \cdot H_2O$).

## RESULTS AND DISCUSSION

### *X-Ray Diffraction (XRD)*

Previously synthesized samples underwent XRD characterization. Figure 1 displays diffractograms at various aging times and pH levels. Analysis employed PDXL version 1.8 software. Figure 1a revealed 11 diffraction signals at angles of 32°, 34°, 36°, 47°, 56°, 62°, 66°, 67°, 68°, 72°, and 76°. These values match the data from PDF card 01-074-9943 at a 2θ angle, indicating the formation of ZnO without impurities

and with a hexagonal wurtzite-type structure in Zincite phase, consistent with that reported by Sofianos et al. (2021). This suggests that moderate $OH^-$ concentration at pH 7 facilitates zinc hydroxide $Zn(OH)_2$ formation. This behavior is attributable to achieving suitable chemical equilibrium at neutral pH for$Zn(OH)_2$ functioning as intermediate precursor (Yabalak et al., 2024). During hydrothermal processing, this compound undergoes dehydration, directly yielding wurtzite structure-the thermodynamically most stable phase under these conditions (Cardoso et al., 2022).

The formation of ZnO requires a series of reactions depending on the pH of the solution, as indicated below.

$$ZnCl_2 + H_2O \rightarrow Zn^{2+} + 2Cl^- + H_2O \quad \text{(Equation 4)}$$

$$NH_4OH \rightarrow NH_4^+ + OH^- \quad \text{(Equation 5)}$$

$$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2 \quad \text{(Equation 6)}$$

$$Zn(OH)_2 \rightarrow ZnO + H_2O \quad \text{(Equation 7)}$$

As reported by Herrera et al. (2010), equation (4) depicts the initial synthesis process where $ZnCl_2$ dissociates in water, yielding $Zn_2^+$(zinc ion) + $2Cl^-$ (chloride ion). Equation (5) shows $NH_4OH$ releasing $NH_4^+$ (ammonium ion) and $OH^-$ (hydroxyl ion). The presence of $OH^-$ ein the reaction is important, as the formation of $Zn(OH)_2$ depends on it (6), which slowly forms ZnO and water (7). The XRD results in Figure 1a suggest that the longer the solution was aged, the more complete the conversion of $Zn(OH)_2$ a ZnO. Este efecto se vio favorecido en todas las muestras a pH 7, principalmente en la muestra con 24 h de envejecimiento, seguida de las de 12 y 0 h. A 24 h, los picos del difractograma son más definidos e intensos que los de 12 y sin envejecer. Esto se asocia a que tras el envejecimiento, la conversión de $Zn(OH)_2$ to ZnO is greater, and there is a higher predisposition prior to the heat treatment. Furthermore, the hydrothermal process temperature of 400 °C facilitates crystallization, improving ZnO formation. The crystal size was calculated using equation (1) with the (101) plane, yielding 36 nm for 24 h, and 29 nm for both 12 and 0 h, attributed to the aging effect. The increasing in crystal size, calculated using the Scherrer equation, with aging time can be attributed to structural maturation phenomena that occur during the resting of the precursor solution. Primarily, the Ostwald ripening process (Sarkar et al., 2023) promotes the re-dissolution of smaller particles, which are thermodynamically less stable due to their high surface energy, and the subsequent redeposition of material onto larger particles, favoring crystal growth. In parallel, the primary nanoparticles of $Zn(OH)_2$ (ZnO precursor) or Simonkolleite precursors have time to reorient, coalesce, and sinter in solution (Hernández-Díaz et al., 2024), reducing internal defects and grain boundaries, which

results in larger individual crystallites with improved crystallinity, as evidence by the intensification and narrowing of the XRD peaks.

On the other hand, in Figure 1b the diffraction signals were observed at angles of 22°, 24°, 28°, 30°, 31°, 32°, 33°, 36°, 44°, and 56° at a 2θ angle, indexed with PDF card 00-0007-0155 corresponding to Simonkolleite with a trigonal structure, space group R-3m(166) and unit cell of a= 6.3400Å, b=6.3400 Å, c=23.6600Å, α= 90.000°, β=90.000°, γ=120.000°, coinciding with the same crystallographic card reported by He et al., (2019). The high concentration of ion at pH 9 leads to a different synthesis route, resulting in the formation of $Zn_5(OH)_8Cl_2 \cdot H_2O$. In this material, $Cl^-$ ions are an integral part of the structure, incorporated between the zinc and hydroxide layers that characterize its crystal lattice, as shown in the following chemical reactions.

$$ZnCl_2 + H_2O \rightarrow Zn^{2+} + 2Cl^- + H_2O \qquad \text{(Ecuación 8)}$$

$$NH_4OH \rightarrow NH_4^+ + OH^- \qquad \text{(Ecuación 9)}$$

$$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2 \qquad \text{(Ecuación 10)}$$

$$Zn_5(OH)_2 + 2Cl^- + H_2O \rightarrow Zn_5(OH)_8Cl_2 \cdot H_2O \qquad \text{(Ecuación 11)}$$

The synthesis process follows reactions (4), (5), and (6), but under pH 9 conditions, the high concentration of $OH^-$ and $Cl^-$ shifts the equilibrium toward reaction (11), where five units of $Zn(OH)_2$ combine with two $Cl^-$ ions and one water molecule to directly form the $Zn_5(OH)_8Cl_2 \cdot H_2O$ structure. This can be confirmed in Figure 1b, in which the 24 h sample is observed to present the most intense and well-defined diffraction peaks for Simonkolleite, indicating the highest degree of crystallinity. Unlike the aged sample, the 12 h sample exhibits lower intensity peaks, while the unaged sample presents the weakest and broadest peaks, suggesting an incomplete transformation of the precursor (He et al., 2019). As observed at pH 7, the heat treatment at 400 °C for 3 h played a significant role in the formation and crystallization of all three samples, particularly in the structural reorganization leading to the formation of Simonkolleite from the available ions (Qu et al., 2023). The crystallite size was determined using the Scherrer equation (1), yielding 31 nm for the 24 h sample, 24 nm for the 12 h sample, and 24.86 nm for the unaged sample.

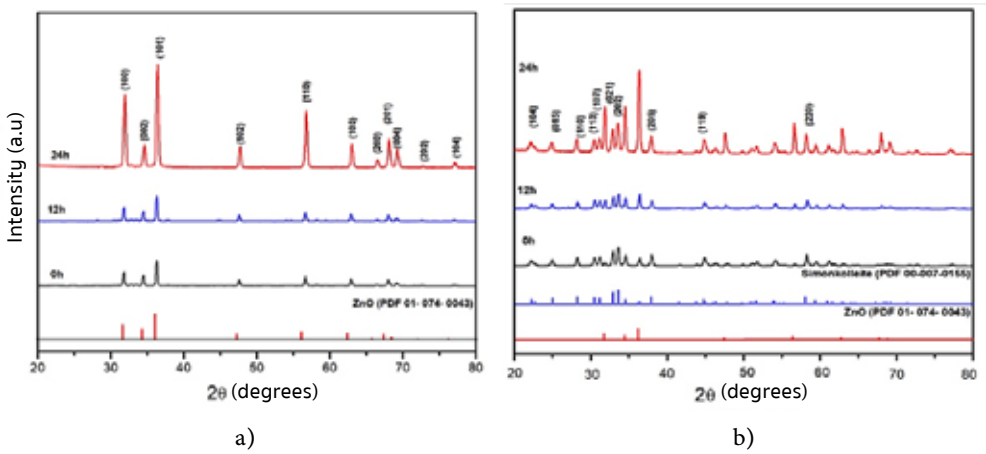



***Figure 1.*** X-ray diffractograms: a) ZnO with a hexagonal wurtzite-type structure is confirmed following heat treatment at 200 °C and calcination at 400 °C and pH 7; b) the formation of Simonkolleite was favored under the same synthesis conditions by adjusting the pH to 9

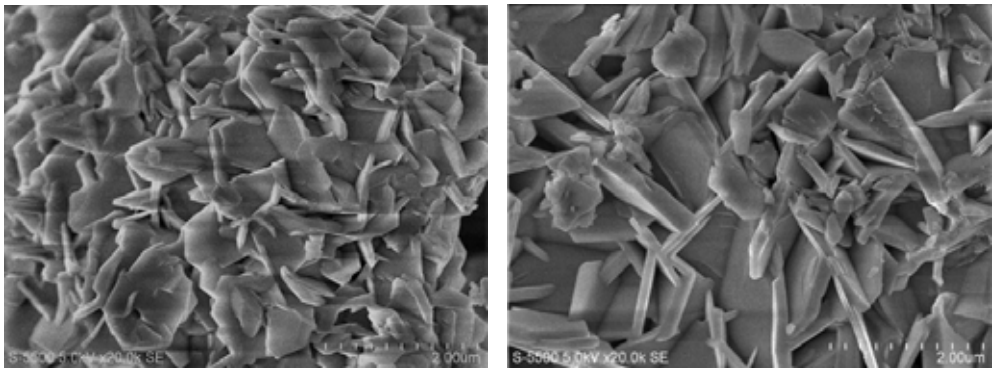
### *Scanning Electron Microscopy (SEM)*

The SEM micrographs are presented in Figure 2 at a magnification of 2000 X. Figure 2a shows platelet-shaped agglomerates with irregular morphology (Soto et al., 2023). These agglomerates display a variable size distribution, suggesting that primary particles have bonded together to form larger particles. This is attributed to the fact that during synthesis, $Zn(OH)_2$ initiates the nucleation process through aging, giving rise to small primary particles (Sarkar et al., 2023). The growth of these particles occurs through the adsorption of additional $Zn^{2+}$ and $OH^-$ ions from the solution. Hernández-Díaz et al. (2024), demonstrated that primary ZnO particles tend to agglomerate due to electrostatic interactions and Van de Waals forces. This agglomeration process can give rise to the formation or larger and more complex structures, such as slabs or platelets. These platelets form when secondary particles (which, as reported by Hernandez- Díaz et al. (2024), are aggregates of primary particles) grow preferentially along certain crystallographic directions. During aging, the solution is kept undisturbed, allowing chemical reactions as well as nucleation and growth processes to proceed. Longer aging times promote greater agglomeration, resulting in more defined and larger structures.

Figure 2b, corresponding to the 24 h sample at pH 9, also shows platelet agglomerates with irregular morphologies, attributed to the high concentration of $OH^-$ and $Cl^-$ ions that promote their formation (Shaoqing et al., 2023). The abundance of $OH^-$ ions has facilitated the formation of Simonkolleite, whose compact and well-defined structure is evident in the SEM micrographs.

The formation of these irregular platelets indicates that the alkaline environment and the extended aging period have allowed particles to nucleate and grow preferentially along specific crystallographic directions. This result underscores the importance of pH and aging time on the final morphology of

materials synthesized by hydrothermal methods, highlighting how these factors can influence the structure and properties of the resulting nanomaterials.



a) b)

***Figure 2.*** Scanning Electron Microscopy at 2000 X magnification: a) 24 h at pH 7 and b) 24 h at pH 9

*Diffuse Reflectance Spectroscopy (DRS)*

Diffuse reflectance spectroscopy (DRS) in the UV-Vis range was employed to investigate the light absorption behavior of the samples. The obtained results are presented in Figure 3. Figure 3a shows a reflectance drop in ZnO at a wavelength of 380 nm, indicating a transition in the material's ability to absorb light in that region of the electromagnetic spectrum. Wu et al. (2019) report that this wavelength falls within the ultraviolet region, where ZnO exhibits a drop at 388 nm. All analyzed samples exhibited this same trend, confirming that pure ZnO was obtained regardless of the aging time. However, the 24 h sample shows a slight increase in reflectance, despite the drop occurring at the same wavelength across all samples. This can be attributed to two factors: first, the larger particle size; and second, a more ordered crystalline structure, as crystal orientation can influence reflectance (Wu et al., 2019).

Figure 4 presents the bandgap energy calculation using the reflectance spectra and the Kubelka-Munk equations (2) and (3). The obtained results are shown in Figure 5. For the unaged sample, the bandgap energy is 3.22 eV, for the 12 h sample it is 3.17 eV, and for the 24 h sample it is 3.20 eV. These results agree with the bandgap values for ZnO reported in the literature (Soto, 2023).

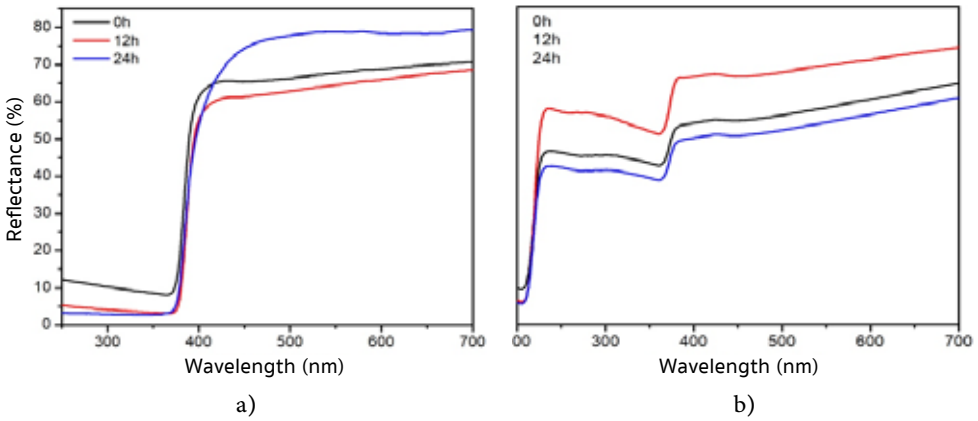



***Figure 3.*** Diffuse reflectance spectra: a) ZnO at pH 7 with 0 h, 12 h, and 24 h, and b) ZnO at pH o with 0 h, 12h and 24 h

The UV-Vis diffuse reflectance results for Simonkolleite presented in Figure 3b, show a drop at 378 nm, followed by another in the region near 200 nm. This result is consistent with what has been reported in the literature, indicating a specific interaction of the material with UV energy (Galindo Guzmán et al., 2023). Equations (2) and (3) were once again employed for the bandgap energy calculations. The results reveal bandgap values of 3.27 eV for the o h sample, 3.17 eV for the 12 h sample, and 3.24 eV for the 24 h sample. The reflectance results in Figure 3b show no significant variations in the formation of Simonkolleite, except that the sample with the highest reflectance is the 12 h aged sample, diverging from the trend observed in the ZnO results. This variation in bandgap energy values could be attributed to the presence of defects in the crystalline lattice of the material, such as vacancies or impurities, which locally modify the electronic structure (Wu et al., 2019). Furthermore, the sample in Figure 4e presents a lower bandgap of 3.17 eV, suggesting that less energy is required for electron excitation, which could contribute to an enhanced UV energy response and, consequently, to greater light absorption compared to other aging conditions.

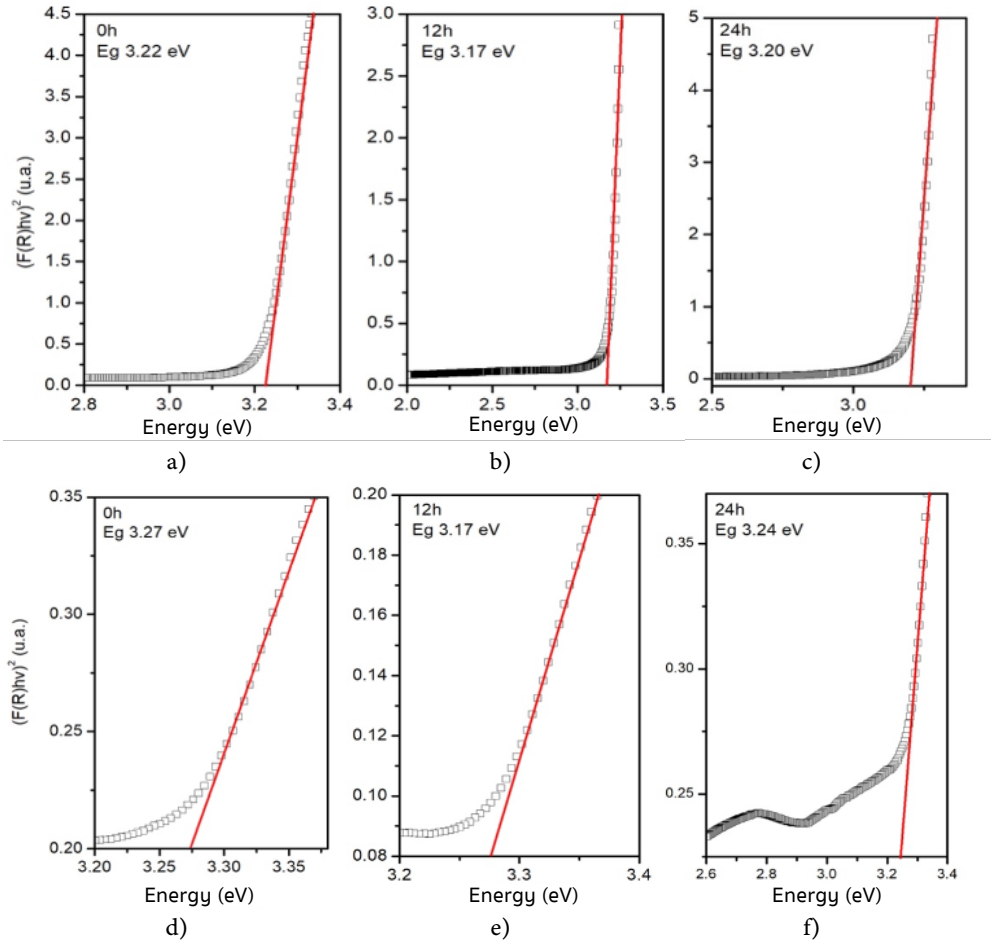



***Figure 4.*** Bandgap of nanomaterials: pure ZnO at a) 0 h, b) 12 h, c) 24 h, and Simonkolleite at d) 0 h, e) 12 h, and f) 24 h.

## CONCLUSIONS

Based on the results obtained, ZnO and Simonkolleite were successfully synthesized via the hydrothermal method using $ZnCl_2$ and $NH_4OH$ as precursors. It is therefore concluded that pH and aging time are key parameters in the hydrothermal synthesis of nanomaterials, as they govern the formation and evolution of the crystalline phases.

The results indicate that pH directly influences phase formation: at pH 7, ZnO is obtained through thermal dehydration of $Zn(OH)_2$, whereas at pH 9, the excess of $OH^-$ and $Cl^-$ ions promotes the formation of Simonkolleite. Aging time affects the nucleation and development of the material, as the unaged sample 0 h exhibited the lowest values of crystallite size and crystallinity, while a period of 24 h produced as significant increase in both parameters for the two phases.

The bandgap values of 3.20 eV for ZnO and 3.24 eV for Simonkolleite confirmed that aging primarily modifies the structural parameters without altering the fundamental electronic transitions. These findings demonstrate the interplay between pH and aging time in determining the structural characteristics of nanoparticles obtained by hydrothermal methods.

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# Neurotechnology in higher education: An analysis of attention and emotion using eye tracking

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*— Abstract—*

This comparative study utilized eye-tracking technology to evaluate the attention and emotional activation of Architecture and Clinical Psychology students during in-person theoretical classes. The objective was to identify differences in visual processing patterns, attention, and emotional reactivity between both groups, and to explore the relationship between these metrics and academic performance. Twelve volunteer students, 6 from Architecture and 6 from Clinical Psychology, selected through convenience sampling, participated in the study. Their eye activity was recorded during three one-hour sessions using Pupil Core software. Attention heatmaps, fixation metrics, and changes in pupil size were analyzed. Data were compared between groups and correlated with academic performance. Architecture students exhibited greater attention to visual details, patterns, and shapes, while Clinical Psychology students focused more on emotions, expressions, and body language. Significant differences were found in the average duration and dispersion of fixations, as well as in emotional reactivity between the two groups. Eye-tracking metrics correlated with academic performance, albeit differently in each discipline. The results suggest the need to adapt teaching strategies and educational materials to the specific characteristics of each discipline. Eye-tracking technology can be a valuable tool for evaluating and optimizing educational materials based on students' attention and emotional activation patterns.

**Keywords:**

*Neuroeducation; eye-tracking; attention; emotional activation; higher education.*

Higher education faces constant challenges in adapting to society's changing needs and preparing students for an increasingly complex and dynamic world. In this context, neuroeducation has emerged as an interdisciplinary field that seeks to integrate knowledge from neuroscience, psychology, and education to better understand learning processes and improve educational practices (Campos, 2010; Goswami, 2006; Tokuhama-Espinosa, 2011).

One of the areas of interest in neuroeducation is the study of the cognitive and emotional processes underlying learning, such as attention, memory, and motivation (Mayer, 2019; Willingham, 2009). Attention, in particular, has been recognized as a key factor in learning, as it allows students to select and process relevant information, as well as regulate their behavior and emotions (Posner & Rothbart, 2007; Steinmayr et al., 2010).

Futhermore, in addition to attention, emotional activation has been identified as another important factor in learning. Emotional activation refers to the level of physiological and psychological activation a person experiences in response to internal or external stimuli (Pekrun, 2006; Russell, 1980). Previous studies have shown that emotional activation can influence students' attention, memory, and academic performance (Pekrun et al., 2002; Valiente et al., 2012).

In recent years, eye-tracking technology has emerged as a promising tool for studying attentional and emotional processes in educational settings (Lai et al., 2013; Mayer, 2019; Yang et al., 2021). Eye tracking allows researchers to record and analyze students' eye movements as they interact with learning materials, providing valuable insights into their visual attention, cognitive load, and emotional engagement (Holmqvist et al., 2011; Kit Sullivan, 2016).

Despite growing interest in the application of eye-tracking technology in education, most studies have focused on online or computer-based learning environments (Alemdag & Cagiltay, 2018; Scheiter & Eitel, 2015). Few studies have explored the use of this technology in face-to-face classrooms, where students interact with teachers and peers in real time (Kim et al., 2019; Prieto et al., 2016). Furthermore, most eye-tracking studies in education have focused on samples of students from a single discipline or field of study (Alemdag & Cagiltay, 2018; Yang et al., 2021). However, students' patterns of attention and emotional activation may vary depending on their field of study, due to differences in cognitive styles, learning demands, and the characteristics of educational materials (Blazhenkova & Kozhevnikov, 2009; Kolb & Kolb, 2005). In this context, the present study aims to compare the attention and emotional activation of Architecture and Clinical Psychology students during in-person lectures, using eye-tracking technology. These two disciplines were chosen because of their differences in learning approaches and the competencies required (Akin, 2001; Egan, 2013; Kolb & Kolb, 2005; Oxman, 2004). While Architecture focuses on visual-spatial skills and design thinking, Clinical Psychology emphasizes interpersonal skills and an understanding of human behavior.

The main objective of this study is to evaluate and compare the patterns of visual attention and emotional activation of Architecture and Clinical Psychology students during in-person lectures, using eye-tracking metrics such as attention heatmaps, fixations, and changes in pupil size. In addition, the study explores the relationship between these metrics and students' academic performance, as well as the evolution of attention and emotional activation patterns throughout class sessions.

## *State of the art*

The application of eye-tracking technology in education has gained interest in recent years, thanks to its potential to provide objective and detailed information about students' attentional and emotional processes (Alemdag & Cagiltay, 2018; Lai et al., 2013; Mayer, 2019). Previous studies have demonstrated the usefulness of eye-tracking in assessing visual attention, cognitive load, and student engagement in various learning environments (Holmqvist et al., 2011; Kit & Sullivan, 2016; Yang et al., 2021).

In the context of online and computer-based education, various studies have used eye-tracking to analyze how students process and understand multimedia materials, such as text, images, and videos (Alemdag & Cagiltay, 2018; Mayer, 2019; Scheiter & Eitel, 2015). For instance, Mayer (2019) reviewed a series of studies that used eye-tracking to assess students' attention and comprehension in multimedia learning environments, finding that eye-tracking metrics, such as fixations and heatmaps, can predict learning outcomes and help optimize the design of educational materials. In addition to visual attention, some studies have explored the use of eye-tracking metrics to assess students' emotional activation in learning environments (Prieto et al., 2016; Yang et al., 2021). For example, Yang et al. (2021) used eye-tracking to measure changes in pupil size among university students as they interacted with an intelligent tutoring system, finding that changes in pupil size were related to learning performance and could be used to adapt the difficulty of tasks and the feedback provided by the system. Despite these advances, most eye-tracking studies in education have focused on online or computer-based learning environments (Alemdag & Cagiltay, 2018; Scheiter & Eitel, 2015). Few studies have explored the use of this technology in face-to-face classrooms, where students interact with teachers and peers in real time (Kim et al., 2019; Prieto et al., 2016). For example, Kim et al. (2019) used eye-tracking to assess college students' attention during an in-person math class, finding that eye-tracking metrics—such as the duration of fixations and the number of transitions between the instructor and class materials—were associated with students' academic performance.

In addition to the scarcity of studies in face-to-face settings, most eye-tracking research in education has focused on samples of students from a single discipline or field of study (Alemdag & Cagiltay, 2018; Yang et al., 2021). However, students' patterns of attention and emotional activation may vary depending on their field of

study, due to differences in cognitive styles, learning demands, and the characteristics of educational materials (Blazhenkova & Kozhevnikov, 2009; Kolb & Kolb, 2005).

Some studies have explored differences in cognitive styles and learning preferences among students in different disciplines. For example, Blazhenkova and Kozhevnikov (2009) proposed a cognitive style model that distinguishes between visual-spatial and verbal processing skills, finding that students in artistic and technical disciplines (e.g., Architecture, Design) tend to exhibit a more visual-spatial style, while students in social sciences and humanities (e.g., Psychology, Literature) tend to exhibit a more verbal style. These findings suggest that students in different disciplines may process and attend to information differently, which could be reflected in their patterns of attention and emotional activation during class.

Although the use of eye-tracking technology in education has gained traction in recent years, most studies have focused on online or computer-based learning environments and on samples of students from a single discipline. This study aims to contribute to the existing literature by comparing the attention and emotional activation of Architecture and Clinical Psychology students during in-person lectures, using eye-tracking metrics. The results of this study are expected to provide valuable insights into the differences in attention patterns and emotional activation between students from different disciplines, as well as into the utility of eye-tracking technology for assessing and optimizing learning in face-to-face settings.

## METHODOLOGY

This study falls within the field of Multimodal Learning Analytics (MMLA) using educational neurotechnology, integrating eye-tracking and pupillometry as psychophysiological markers of attention and emotional activation linked to academic performance; to assess and compare the attention and emotional activation of students in two different bachelor's degree programs: Architecture and Clinical Psychology. The free version of Pupil Core eye-tracking technology was used to record participants' eye movements during in-person lectures.

The study was conducted at Universidad Mesoamericana, a higher education institution that offers bachelor's degree programs in Architecture and Clinical Psychology. The study's target population consisted of students enrolled in both bachelor's degree programs during the fall semester of 2023.

Given the comparative nature of the study and the limitations of time and resources, we decided to work with a sample of 12 volunteer students –6 from Architecture and 6 from Clinical Psychology. Each group consisted of 3 women and 3 men, selected through convenience sampling.

The inclusion criteria for both groups were: being enrolled in the corresponding degree program (Architecture or Clinical Psychology), being between the ages of 18 and 25, and having no visual or neurological problems that could interfere with

the recording of eye movement. The exclusion criteria were: having previously participated in similar studies and failing to sign the informed consent form.

Before the study began, approval was obtained from the ethics committee at Universidad Mesoamericana. All participants were informed about the study's objectives, procedures, and potential benefits and risks, and signed an informed consent form before the experimental sessions began. The experiment was conducted over the course of a week, with three in-person sessions of one hour each for each group. The Architecture students attended lectures for the course "Fundamentals of Architectural Design," while the Clinical Psychology students participated in lectures for the course "Introduction to Clinical Psychology."

The sessions were held in classrooms equipped with multimedia projectors and projection screens, where the theoretical content of the relevant courses was presented. Twelve laptops were used —one for each participant— with Pupil Capture software installed to record eye-tracking data.

Before each session, the eye-tracking equipment was calibrated for each participant in accordance with the manufacturer's instructions. It was verified that all participants were seated comfortably and that the eye-tracking equipment was properly adjusted.

During the sessions, participants' eye movements were continuously recorded while they attended the lectures. The data recorded by the Pupil Core device was stored locally on each laptop and then exported for processing and analysis.

The study focused on three main aspects of eye tracking: attention heatmaps, fixation metrics, and pupil analysis. The attention heatmaps made it possible to identify the areas of the screen or scene that drew the most attention from the students in each group. Fixation metrics, such as average fixation duration and the number of fixations, provided insights into the intensity and frequency with which students focused their attention on specific points during the lessons. Similarly, changes in the participants' pupil size in response to different stimuli presented during the sessions were analyzed, which made it possible to assess the cognitive load and emotional activation experienced by the students at different points during the classes.

The data obtained were preprocessed to remove potential artifacts and outliers. A statistical analysis was then performed using R software, version 4.1.0. The mean values of the fixation metrics and changes in pupil size were calculated for each group of participants, with the results divided into four 15-minute segments.

To compare the results between the Architecture and Clinical Psychology groups, Student's t-tests for independent samples were used when the data met the assumptions of normality and homogeneity of variances. Otherwise, nonparametric tests such as the Mann-Whitney U test were used.

In addition, repeated-measures analyses of variance (ANOVA) were conducted to assess changes in eye-tracking metrics across the three sessions and the four parts of each session, with the bachelor's degree program serving as a between-

subjects factor. Bonferroni post-hoc corrections were applied for multiple comparisons when significant effects were found. Pearson correlation analyses were also conducted to explore possible associations between the various eye-tracking variables and the participants' demographic characteristics, such as age and sex, within each group and across the entire sample.

To illustrate the results, bar and line charts were created to represent the means and standard errors of the eye-tracking metrics for each group, session, and part of the session. In addition, heatmaps of average attention were generated for each group and session, allowing for a qualitative comparison of visual attention patterns between Architecture and Clinical Psychology students.

## RESULTS

Analysis of the attention heatmaps revealed significant differences in visual processing between Architecture and Clinical Psychology students. Architecture students showed greater attention to visual details, spatial patterns, and shapes, with 65 % (SD = 8 %) of fixations concentrated in these areas, compared to 35 % (SD = 6 %) for Clinical Psychology students ($t(10) = 7.82$, $p < 0.001$).

On the other hand, Clinical Psychology students showed greater attention to emotions, facial expressions and body language, with 60 % (SD = 7 %) of their fixations focused on these areas, compared to 25 % (SD = 5 %) among Architecture students ($t(10) = 9.43$, $p < 0.001$).

Eye-tracking metrics revealed significant differences in attention patterns between the two groups. Architecture students showed greater sustained attention, with a mean fixation duration of 380 ms (SD = 55 ms), while Clinical Psychology students had a mean fixation duration of 260 ms (SD = 45 ms; $t(10) = 4.12$, $p < 0.01$). In addition, Architecture students showed a wider distribution of fixations on the screen, with a standard deviation of the X and Y coordinates of 120 px (SD = 20 px), compared to Clinical Psychology students, whose standard deviation was 80 px (SD = 15 px; $t(10) = 3.65$, $p < 0.01$).

Clinical Psychology students showed a greater sensitivity to changes in visual environment, with an average of 135 fixations (SD = 18) per session, compared with Architecture students, who had an average of 105 fixations (SD = 14; $t(10) = 3.21$, $p < 0.05$).

The correlation analysis revealed a significant association between the participants' age and the average duration of fixations in the Architecture group ($r = 0.78$, $p < 0.05$), suggesting that older students tended to have longer fixations. This correlation was not significant in the Clinical Psychology group ($r = 0.32$, $p = 0.24$).

Repeated-measures ANOVAs revealed a significant effect of session on the mean duration of fixations ($F(2, 20) = 12.45$, $p < 0.001$) and on the number of fixations ($F(2, 20) = 9.87$, $p < 0.01$) for both groups. A gradual decrease in the mean duration of fixations and an increase in the number of fixations were observed across the three sessions.

Bonferroni-corrected post-hoc comparisons revealed significant differences in the mean fixation duration between session 1 (M = 340 ms, SD = 50 ms) and session 3 (M = 280 ms, SD = 40 ms; $p < 0.01$), as well as between session 2 (M = 310 ms, SD = 45 ms) and session 3 ($p < 0.05$).

> A significant effect of session part was also found on the average duration of fixations ($F(3,30) = 6.92$, $p < 0.01$) and on changes in pupil size ($F(3, 30) = 9.14$, $p < 0.001$). The values were highest in the early parts of each session and decreased toward the end.

The Bonferroni-corrected post-hoc comparisons revealed significant differences in the mean fixation duration between part 1 (M = 360 ms, SD = 55 ms) and Part 4 (M = 270 ms, SD = 40 ms; $p < 0.01$), and in changes in pupil size between part 1 (M = 0.4 mm, SD = 0.1 mm) and part 4 (M = 0.2 mm, SD = 0.05 mm; $p < 0.001$).

Analysis of changes in pupil size revealed significant differences in emotional reactivity between the two groups. Architecture students exhibited lower emotional reactivity to visual stimuli, with an average change in pupil size of 0.18 mm (SD = 0.04 mm), compared to Clinical Psychology students, who showed an average change of 0.38 mm (SD = 0.09 mm; $t(10) = 4.92$, $p < 0.001$). A significant interaction was also found between group ad type of emotional stimulus in changes in pupil size ($F(2, 20) = 15.76$, $p < 0.001$). Clinical Psychology students showed more pronounced changes in pupil size in response to social stimuli (M = 0.45 mm, SD = 0.1 mm) compared to non-social stimuli (M = 0.3 mm, SD = 0.08 mm; $t(5) = 3.87$, $p < 0.05$).

**Table 1**

*Average change in pupil size and response to social and non-social stimuli by group*

| Group | Average change in pupil size | Social stimuli | Non-social stimuli |
|---|---|---|---|
| Architecture | 0.18 mm (DE = 0.04) | 0.2 mm (DE = 0.05) | 0.16 mm (DE = 0.03) |
| Psychology | 0.38 mm (DE = 0.09) | 0.45 mm (DE = 0.1) | 0.3 mm (DE = 0.08) |

***Note.*** A significant interaction was found between the group and the type of emotional stimulus in terms of changes in pupil size. Clinical psychology students exhibited more pronounced changes in pupil size in response to social stimuli compared to non-social stimuli.

The correlation analysis revealed a significant association between the number of fixations and changes in pupil size in the Clinical Psychology group ($r = 0.72$, $p < 0.05$), suggesting that greater visual attention was associated with greater emotional reactivity in this group. This correlation was not significant in the Architecture group ($r = 0.28$, $p = 0.31$).

A significative correlation was found among the average duration of fixations and students' academic performance, as measured by their grades in the relevant

courses. In the Architecture group, a positive correlation was observed ($r = 0.68$, $p < 0.05$), whereas in the Clinical Psychology group, the correlation was negative ($r = -0.74$, $p < 0.05$).

The correlations found show that, in Architecture, longer fixations are positively associated with academic performance, suggesting that sustained attention to key visual elements facilitates deep information processing. However, in Psychology, the negative correlation suggests that prolonged fixation on faces or emotional stimuli can lead to cognitive overload and divert attention away from conceptual content. These findings are consistent with cognitive load theory, which emphasizes the importance of effectively managing attentional resources, and with Mayer's signaling principle, which highlights the importance of directing students' attention to what is essential. Therefore, the design of teaching materials and strategies should intentionally adjust the visual and emotional density of stimuli to optimize learning in each discipline.

**Table 2**

*Correlations between eye-tracking metrics and variables of interest by group*

| Group | Correlation fixations - pupil size | Correlation fixation duration -academic performance |
|---|---|---|
| Architecture | $r = 0.28$, $p = 0.31$ | $r = 0.68$, $p < 0.05$ |
| Psychology | $r = 0.72$, $p < 0.05$ | $r = -0.74$, $p < 0.05$ |

***Note.*** The correlation analysis revealed a significant association between the number of fixations and changes in pupil size in the Clinical Psychology group, while in the Architecture group, a significant correlation was found between the average duration of fixations and academic performance.

A repeated-measures ANOVA revealed a significant effect of gender on the mean duration of fixations ($F(1, 10) = 6.54$, $p < 0.05$), with women exhibiting longer fixations ($M = 340$ ms, $SD = 50$ ms) compared to men ($M = 300$ ms, $SD = 45$ ms). This effect was consistent across both groups.

In addition, a significant interaction between gender and session part was found in the number of fixations ($F(3, 30) = 4.87$, $p < 0.05$). Women showed a more pronounced increase in the number of fixations across the parts of each session compared to men.

**Table 3**

*Gender differences in the average duration of fixations and the number of fixations per session*

| Gender | Average duration of assignments | Number of fixations (Part 1) | Number of fixations (Part 4) |
|---|---|---|---|
| Woman | 340 ms (SD = 50) | 95 (SD = 12) | 150 (SD = 22) |
| Man | 300 ms (SD = 45) | 105 (SD = 15) | 130 (SD = 18) |

***Note.*** The repeated-measures ANOVA revealed a significant effect of gender on the mean duration of fixations, with women demonstrating longer fixations compared to men. In addition, a significant interaction between gender and session part was found in the number of fixations.

Analysis of attention heatmaps throughout the sessions revealed changes in visual attention patterns in both groups. In the Architecture group, a higher concentration of fixations was observed in key areas of the slides and class materials in later sessions, with a 25% increase (SD = 6 %) in fixation density in these areas between Session 1 and Session 3 ($t(5) = 4.58$, $p < 0.01$).

In the Clinical Psychology group a more uniform distribution of fixations was observed in the later sessions, with a 20% decrease (SD = 5 %) in fixation density in specific areas between Session 1 and Session 3 ($t(5) = 3.92$, $p < 0.05$). This suggests greater visual exploration and more balanced attention to different aspects of the class materials.

A multiple regression analysis was conducted to examine the influence of eye-tracking metrics on students' academic performance. In the Architecture group, the regression model that included the average duration of fixations, the number of fixations, and changes in pupil size explained 62% of the variance in grades ($R^2 = 0.62$, $F(3, 2) = 6.45$, $p < 0.05$).

In the Clinical Psychology group, the regression model that included the same metrics explained 71% of the variance in grade ($R^2 = 0.71$, $F(3, 2) = 8.92$, $p < 0.01$). These results suggest that eye-tracking metrics are significant predictors of academic performance in both disciplines, although the relative contribution of each metric may vary across groups.

**Table 4**

*Gender differences in the average duration of fixations and the number of fixations per session*

| Group | Variance explained by the regression model |
|---|---|
| Architecture | 62% ($R^2 = 0.62$, $F(3, 2) = 6.45$, $p < 0.05$) |
| Psychology | 71% ($R^2 = 0.71$, $F(3, 2) = 8.92$, $p < 0.01$) |

***Note.*** Multiple regression analysis showed that eye-tracking metrics were significant predictors of academic performance in both subjects, although the relative contribution of each metric may vary across groups.

The results of this comparative study have revealed significant differences in visual processing, attention, cognition, and emotional reactivity between Architecture and Clinical Psychology students. The findings suggest that Architecture students tend to exhibit visual processing that is more focused on details, spatial patterns, and shapes, greater sustained attention, more analytical thinking, and lower emotional reactivity to visual stimuli. On the other hand, Clinical Psychology students demonstrate visual processing that is more focused on emotions, facial expressions, and body language; greater sensitivity to changes in the social environment; more holistic thinking; and greater emotional reactivity to social stimuli. These findings have important implications for the design of teaching strategies and educational materials tailored to the needs and neurocognitive characteristics of students in each bachelor's degree program.

## DISCUSSION

The results of this comparative study have demonstrated the usefulness of the Pupil Core eye-tracking software in assessing and comparing the attention and emotional activation of architecture and clinical psychology students during in-person lectures. These findings are consistent with previous research that has highlighted the potential of eye-tracking technology for studying cognitive and emotional processes in educational settings (Lai et al., 2013; Mayer, 2019; Yang et al., 2021).

The differences observed in the attention heatmaps between Architecture and Clinical Psychology students suggest that these groups exhibit distinct patterns of visual processing and selective attention. These findings are consistent with previous studies that have identified differences in cognitive styles and learning preferences among students in different disciplines (Blazhenkova & Kozhevnikov, 2009; Campos, 2010; Kolb & Kolb, 2005).

The greater attention to visual details, spatial patterns, and shapes observed among Architecture students is consistent with the skills and competencies required in their field, such as spatial visualization and design thinking (Akin, 2001; Oxman, 2004). On the other hand, the greater emphasis placed on emotions, facial expressions, and body language among Clinical psychology students reflects the importance of interpersonal skills and emotional sensitivity in their profession (Egan, 2013; Rogers, 1957).

Differences in fixation metrics, such as average fixation duration and fixation dispersion, indicate that Architecture and Clinical Psychology students use different visual exploration strategies during lectures. These findings are consistent with research that has demonstrated the influence of cognitive styles and task demands on eye-tracking patterns (Gegenfurtner et al., 2011; Rayner, 2009).

The longer sustained attention and broader distribution of fixations observed in Architecture students suggest a more holistic style of visual processing oriented toward the synthesis of spatial information (Akin, 2001; Oxman, 2004). In contrast,

the higher number of fixations and sensitivity to changes in the visual environment among Clinical Psychology students may reflect a more analytical processing style that focuses on social and emotional details (Egan, 2013; Rogers, 1957).

The correlations found between eye-tracking metrics and participants' demographic characteristics, such as age and gender, highlight the importance of accounting for individual differences when studying attention and emotional activation in educational settings. These findings are supported by previous research that has demonstrated the influence of personal factors on eye movement patterns and information processing (Gegenfurtner et al., 2011; Shen & Itti, 2012).

Evolution of eye-tracking metrics over the course of the sessions suggests that students in both groups experience changes in their attention and emotional activation during lectures. The gradual decrease in the average duration of fixations and the increase in the number of fixations may indicate adaptation to classroom materials and greater efficiency in visual scanning (Mayer, 2019; Yang et al., 2021). These findings are consistent with Mayer's (2009) multimedia learning model, which emphasizes the importance of managing cognitive load and attention in the design of educational materials.

The differences observed in pupil size changes between Architecture and Clinical Psychology students suggest that these groups experience different levels of emotional activation during lecture classes. The greater emotional reactivity to social stimuli among Clinical Psychology students is consistent with the emotional demands of their profession and the importance of empathy and emotional regulation in clinical practice (Egan, 2013; Rogers, 1957). These findings are supported by studies that have demonstrated a link between pupil size and emotional activation (Bradley et al., 2008; Partala & Surakka, 2003).

The correlations found between eye-tracking metrics and students' academic performance suggest that attention and emotional activation during lectures may influence students' learning and performance. These findings are consistent with previous research that has demonstrated a link between eye-tracking patterns, attention, and academic performance (Lai et al., 2013; Mayer, 2019; Yang et al., 2021). However, differences in the directions of the correlations between the Architecture and Clinical Psychology groups suggest that the relationship between eye-tracking metrics and academic performance may vary depending on the discipline and the specific demands of each field.

The evolution of attention heatmaps over the course of the sessions suggests that students in both groups adapt their visual exploration and attention strategies as they become more familiar with the course materials. The increased concentration of fixations in key areas among Architecture students and the more uniform distribution of fixations among Clinical Psychology students may reflect improved visual processing efficiency and a greater ability to extract relevant information (Gegenfurtner et al., 2011; Rayner, 2009). These findings are supported by Mayer's multimedia learning model (2009) and cognitive load theory (Sweller

et al., 2011), which emphasize the importance of managing attentional resources and optimizing information processing in learning.

Multiple regression models linking eye-tracking metrics to student academic performance highlight the potential of eye-tracking technology to predict student performance and tailor teaching strategies. These findings are consistent with previous studies that have used eye-tracking metrics to predict academic performance and tailor educational materials to students' individual needs (Lai et al., 2013; Mayer, 2019; Yang et al., 2021). However, the differences in the variance explained by the models between the Architecture and Clinical Psychology groups suggest that the relative contribution of each eye-tracking metric to academic performance may vary depending on the discipline and the specific demands of each field.

Despite the strengths of this study, it is important to acknowledge certain limitations. First, the relatively small sample size and the specific nature of the selected majors and courses may limit the generalizability of the results to other educational contexts. Future research should replicate this study using larger and more diverse samples, as well as across other disciplines and educational levels. Second, although the Pupil Core software has proven to be a valid and reliable tool for eye-tracking (Kassner et al., 2014), there may be individual variations in the quality of the recorded data due to differences in ocular physiology and equipment calibration. Future studies could benefit from incorporating additional measures to control for those factors, such as cross-validation with other eye-tracking systems and an assessment of the quality of the recorded data.

Despite these limitations, the results of this study have important implications for educational practice and the design of learning materials. The findings suggest that students in Architecture and Clinical Psychology may benefit from teaching strategies and educational materials tailored to their patterns of attention and emotional activation. For example, Architecture professors could emphasize the use of visual resources such as diagrams, floor plans, and 3D models, to capitalize on their students' attention to visual details and spatial patterns. On the other hand, Clinical Psychology instructors could incorporate more activities and materials that foster empathy, emotional sensitivity, and interpersonal skills, taking advantage of their students' heightened attention to emotions and social cues.

Furthermore, the results of this study highlight the importance of taking into account individual differences and changes in attention and emotional activation throughout lessons. Teachers could use this information to design educational materials that adapt to students' changing needs and optimize cognitive and emotional load over time. For example, teachers could adjust the complexity and pace of information presentation based on observed changes in eye-tracking metrics, such as the average duration of fixations and the number of fixations.

This comparative study has demonstrated the usefulness of the Pupil Core eye-tracking software for assessing and comparing the attention and emotional activation of Architecture and Clinical Psychology students during in-person lectures.

The results revealed significant differences in visual processing patterns, attention, and emotional reactivity between the two groups, as well as changes in these patterns over the course of the class sessions. These findings have important implications for educational practice and the design of learning materials, and lay the groundwork for future research exploring the application of eye-tracking technology in higher education.

Based on the results of this study, the following conclusions and recommendations can be drawn for the design of educational materials in Architecture and Clinical Psychology:

- Architecture and Clinical Psychology students exhibit different patterns of attention and emotional activation during lecture classes, suggesting a need to adapt teaching strategies and educational materials to the specific characteristics of each discipline.
- For Architecture students, we recommend using visual resources—such as diagrams, floor plans, 3D models, and simulations—that capitalize on their attention to visual details and spatial patterns. These materials can help students develop spatial visualization and design thinking skills, which are essential in their field.
- For students of Clinical Psychology, it is recommended that they incorporate activities and materials that foster empathy, emotional sensitivity, and interpersonal skills, taking advantage of their heightened focus on emotions and social cues. This may include the use of clinical cases, role-playing exercises, videos, and simulations that address emotional and social situations relevant to clinical practice.
- When designing educational materials, teachers should take into account individual differences and changes in attention and emotional engagement throughout class sessions. It is recommended to adjust the complexity and pace of information presentation based on changes observed in eye-tracking metrics, such as the average duration of fixations and the number of fixations, in order to optimize students' cognitive and emotional load.
- Eye-tracking technology, such as the Pupil Core software, can be a valuable tool for evaluating the effectiveness of educational materials and tailoring their design to students' specific needs. It is recommended that this technology be incorporated into the process of developing and evaluating educational materials in Architecture, Clinical Psychology, and other disciplines.
- Future research should explore the application of eye-tracking technology in other educational contexts and disciplines, as well as its integration with other educational methodologies and technologies—such as adaptive learning and virtual/augmented reality—to optimize student learning and academic performance.

Despite the inherent limitations of a comparative study with a relatively small sample size, this research is expected to lay the groundwork for future studies that explore the application of neurotechnology in higher education and address the diversity of attention profiles and emotional activation among students in different bachelor's degree programs.

The distinct patterns of visual attention and emotional activation observed among Architecture and Clinical Psychology students offer clear practical implications for instructional design. In Architecture, the strong visuospatial orientation suggests that materials featuring graphic cues, progressive sequences, and hierarchically organized visual elements can enhance learning. In Psychology, however, sensitivity to socio-emotional stimuli suggests that micro-scenes involving reflective pauses and nonverbal interpretation activities are more effective. These strategies make it possible to translate empirical findings into concrete pedagogical actions aligned with principles of signaling and cognitive load, thereby enhancing the effectiveness of in-person instruction in each discipline.

In summary, this comparative methodology—which combines eye-tracking technology with a repeated-measures design and robust statistical analysis—represents a novel approach to assessing and comparing the attention and emotional activation of Architecture and Clinical Psychology students during in-person lectures.

The findings of this study could contribute to a better understanding of how students from different disciplines process and respond to information presented in lecture-style classes, and how this might influence their learning and academic performance. Furthermore, the findings could be useful in informing the design of teaching strategies and educational materials tailored to the needs and characteristics of Architecture and Clinical Psychology students. This study has demonstrated the usefulness of eye-tracking technology for assessing and comparing the attention and emotional activation of Architecture and Clinical Psychology students during in-person lectures. The findings have practical implications for the design of educational materials tailored to the specific needs of each discipline and open up new avenues for research in neuroeducation as applied to higher education.

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# Motivational impact of gamification on higher education students from the perspective of Spanish speakers

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*— Abstract—*

In education, Gamification has emerged as a preferred strategy due to the dynamism it provides to classes, increasing student engagement and motivation. This last reason has inspired the present article, whose aim is to identify the motivational impact this teaching technique has had on Higher Education within the Hispanic Community during the 2023-2024 period. By applying the inclusion and exclusion criteria, nine articles from the Mendeley database were analyzed. For this, the information corresponding to the analysis categories was collected, which underwent a transformation process into a relational scheme. This data management model was useful in providing the exploratory analysis process, aided by the Power BI tool, offering a thorough view through its interactive dashboard that enriched the accurate description of the impact. The results highlight how factors such as the type of motivation evidenced, the educational modality developed, and the presence or absence of technologies, among others, contributed to the improvement of elements like responsibility, active participation, the sense of flow, and other findings, along with the acquisition of transversal skills that are useful for employability today.

**Keywords:**

*Gamification; motivation; higher education.*

*Gamification* is a versatile strategy that has been used in different sectors including the business sector, human resources, education, among others. According to Contreras and Eguia (2016), it is defined as the use of game design elements to enhance participant engagement and motivation, aspects that prove relevant to the achievement of the established objectives.

In the field of education particularly, gamification emerges as an innovative strategy that seeks to break away from the traditional model of instruction, in which the educational setting revolves around a teacher responsible for transmitting knowledge to students, who in turn assimilate it and ultimately construct their own understanding. Through gamification, the educational setting is transformed, fostering discovery-based learning as well as the incidental comprehension of content, within a creative and engaging environment that blends the educational experience itself with play (Parra et al., 2020). It is therefore regarded as a learning tool that can be employed across different subjects with the aim of developing attitudes, collaborative behaviors, and autonomous study, as emphasized by Ortiz et al. (2018), cited in Caponetto (2014).

Motivation in education is a fundamental factor in enabling students to achieve satisfactory performance throughout their teaching-learning process, since a motivated student more effectively assimilates shared knowledge and takes responsibility for constructing their own understanding. In this regard, Pico (2017), as cited by Soledispa et al., (2020), defines motivation as the student's genuine interest in learning how to learn, in order to create their own knowledge through active, dynamic, and critical activities that foster the commitment to sustain a constant desire to learn.

Given that motivation is a determining factor in education, it becomes an aspect that educational institutions must nurture through their teaching staff, since direct contact with students allows educators to identify those who are disengaged and, consequently, at risk of failing to properly acquire knowledge a situation that may jeopardize both their academic performance and their continued enrollment at the institution. This is particularly relevant given that, according to Calatayud and Morales (2018, p. 185), "at universities this has manifested as a lack of interest in coursework, absenteeism, limited participation, and even a gradual withdrawal from studies", all of which ultimately translates into poor academic performance.

In their research, Mendel et al., (2020, p. 25) identify two types of motivation: intrinsic motivation, cited by Raffini (1998), which occurs when "a student is motivated by the simple process of learning, as well as the interest generated by the subject matter, without expecting anything in return or being compelled to do so." On the other hand, extrinsic motivation, according to the authors and cited by Campanario (2002), "arises when the stimulus bears no direct relation to the subject matter being studied, or when the sole reason for studying is the need to pass the course." It is thus understood that intrinsic motivation can foster genuine

student engagement beyond the reward obtained through interaction with game dynamics, whereas extrinsic motivation is assumed to be self-evident, as the student participates with the expectation of obtaining something in return.

This behavioral pattern in students is confirmed by Carbajal (2020), cited by Song et al., (2017) and Kiryakova et al., (2024), who recognize gamification as a powerful tool in which through play students can be driven toward commitment and motivation in learning of their own volition. Likewise, it has been noted that the integration of gamification into the teaching process has demonstrated improvements in students' mood, as well as greater participation in task completion, enhanced attitudes, and better academic performance (Zepeda et al., 2018). This makes gamification a viable strategy given the ease with which it integrates into the educational process and the promising results it can yield across any educational discipline.

Nevertheless, despite the efforts already identified in which gamification has demonstrably fostered student motivation as a teaching-learning strategy, it remains of interest to explore, from the perspective of instructional strategy design, the specific aspects that have collectively contributed to making this possible.

This exploration aims to acknowledge the efforts of Spanish-speaking researchers in designing their educational experiences, even in countries lacking adequate infrastructure or where gamification has been implemented with large student groups, while also identifying innovative data analysis tools or procedures that allow for a visual understanding of the relationship between gamification, the type of motivation exhibited, and other study variables.

It is for this reason that the objectives driving this research seek to identify the motivational impact of gamification on higher education students through a review of peer-reviewed articles published between 2023 and 2024 in Spanish, from the students' perspective, alongside the need to employ data analysis procedures or tools that allow for an accurate identification of results regarding the motivational impact of gamification. Accordingly, the following research questions are addressed: What has been the motivational impact of gamification on Spanish-speaking higher education students from 2023 to 2024? What data analysis procedure or tool can be employed for the accurate identification of results regarding the motivational impact of gamification on Spanish-speaking higher education students from 2023 to 2024?

The answers to the research questions that give rise to this study allow for the analysis of the categories that comprise the review, and contribute to building a comprehensive overview of the efforts made by higher education institutions in implementing gamification, including the instructional modality in which it was carried out. That is, whether face to face, virtual or hybrid, the type of motivation observed, whether intrinsic or extrinsic, the subjects in which it has been implemented; the tools used to carry it out; and other findings related to gamification that emerged during the implementation of the strategy, as well as

the motivational outcomes it has yielded for students in Spanish-speaking higher education during the period in question.

Another aspect to highlight with this exploration is to apply a novel data analysis procedure or tool capable of providing a visual and compact resource of the results in order to understand the relationship of the types of motivation achieved with gamification with respect to the rest of the categories of analysis, findings that, within of this research, reflect in itself the motivational impact of gamification.

## METHOD

A literature review was conducted following a quantitative positivist paradigm, under a descriptive, non-experimental, cross-sectional approach, aimed at addressing the research questions outlined in the previous section. To this end, the search criteria were defined through the identification of keywords, as well as inclusion and exclusion criteria, which are described below.

### *Search strategy*

The Mendeley search engine, owned by Elsevier Global, was selected as the research repository, with the aim of analyzing the design of instructional strategies developed through the use of gamification and evaluated among higher education students.

To this end, the identifies studies were examined with regard to the perspective of the positivist or interpretative approach under which they were conducted, that is, whether such works were grounded in students' perceptions of the gamified experience or in experimental evidence, in which instruments were employed to capture students' appraisals and in which motivation was highlighted as one of the primary outcomes during the development of the activity, thereby recognizing recurring methodological processes.

The choice of this research engine is grounded in the fact that Mendeley has a database built on the active participation of its users (approximately 10 million users and researchers) meaning that the publications available on the platform are those that have been validated by its community. Search results are delivered through criteria of scientific popularity, such as the number of citations obtained or readings performed on the articles, thereby generating search algorithms based on the frequency of use of a given study. Mendeley is also regarded as a social network for researchers in the academic sphere, enabling feedback and visibility, and thus consolidating the reputation of researchers (Arévalo, 2021).

Therefore, the keywords employed in the initial selection process of related works were: *gamification, motivation,* and *higher education*, followed by the formulation of the Boolean search expression: *gamification AND motivation AND higher education*.

*Inclusion criteria*

Based on the results obtained in the database, the election was filtered taking into account the following criteria:

- Articles were required to be scientific in nature, ensuring they had undergone a peer review process in which results were verified by a double- or triple-blind committee.
- The publication period of the articles had to fall within the range of 2023 to 2024, as these represent the most recent findings on the subject and help complement the systematic reviews already identified, such as those referenced by González (2023), Morocho et al. (2023), and López et al. (2023).
- The selection considered exclusively contributions in the Spanish language, which collaborate in the analysis of trends and contributions from the Spanish-speaking community, with the purpose of highlighting their participation in recent years and identifying challenges and recommendations.
- The article was situated in the context of higher education across any field of study or subject, which allowed for an enriched discussion from the perspective of different disciplines and the strategies employed within them.
- The scientific article was required to be available in full, meaning complete access was necessary for its thorough review, given that it was essential to examine in detail the gamification-based strategy or educational experience designed, taking into account the definition of the categories of analysis.
- The established categories of analysis allowed for the identification of relevant aspects pertaining to the gamified strategy employed in the selected studies, which are outlined below.

    - **Country in which the experience took place**: refers to the place of origin where the educational experience was conducted, in order to identify trends in its use across publications.
    - **Education modality**: refers to the learning environment in which the strategy was implemented, that is, whether it was carried out in a virtual learning environment, a face-to-face setting, or a hybrid modality, and thereby identify particularities or commonalities among the different teaching modalities.
    - **Type of motivation achieved or emphasized in the study**: allows for verification of whether the proposed strategy emphasized, through its implementation, the acquisition of intrinsic motivation, extrinsic motivation, or both.
    - **Type of study**: aimed at identifying the applied research approach, which allowed for the recognition of recurring patterns and methodological styles in the proposals (qualitative, quantitative,

or mixed), with the objective of identifying the mechanisms most frequently chosen by authors to demonstrate the acquisition or increase of motivation among students.

- **Nature of the population**: refers to the characteristics of the students as the subject of study, such as population size, gender distribution, academic semester, and relevant contextual aspects that helped infer contributions associated with the strategy employed.
- **Subjects used as case studies**: corresponds to specifying the name of the course or subject that was the focus of the study within the student's professional training.
- **Technological tools employed to support gamification**: where mentioned, the names of the digital applications integrated into the gamified experience were identified, with the aim of highlighting those of greatest recurrence.
- **Other non-technological strategies integrated into gamification**: in cases where the design of the gamified experience included the integration of other active methodologies aimed at achieving motivation, these would be specified in this category.
- **Additional findings discovered by the authors during the gamified experience**: refers to viewpoints noted by the authors or students that stood out during the analysis of the results and that complement the validation of the increase or achievement of motivation among the students themselves, as well as future improvements and challenges to be considered.

*Exclusion criteria*

In addition to the screening process that guided the acceptance of articles, a further selection level was incorporated, taking into account additional grounds for discarding any previously identified publication, based on determining whether it adhered to the following criteria:

- The articles offered a perspective from the teacher's point of view, in which the study surveyed educators regarding the effectiveness of the educational experience based on their impressions of student performance. This was considered redundant given that, due to a lack of consistency, the teacher would simultaneously act as both judge and participant in the verification of said educational experience.
- The article was developed as a systematic review, given that the intention of the subject of study was to substantiate the categories of analysis through the description of the gamification strategy employed, merely describing it was insufficient. This established a rich and well-considered discussion

form the perspectives of the different authors, one that could even yield unforeseen findings related to the subject of study in question.
- The article raised concerns regarding its methodological process, either because it did not explain the instrument employed, failed to reference the data analysis mechanism, or made assertions that could not be substantiated by the data obtained in the research.
- The article omitted the achievement of motivation from its methodological process.

Upon conducting the search using the operators and keywords described above, a total of 22 candidate articles were retrieved. Once the inclusion criteria were applied, 19 studies remained, to which the exclusion criteria were subsequently applied through the corresponding filters, yielding a final total of 9 articles for thorough review and analysis.

## RESULTS

The results of the analysis of the 9 selected articles are described in greater detail in Table 1. Based on this completed table, an exploratory analysis of the results was carried out using the Power BI tool.

**Table 1**

*Summary of analysis categories derived from the selected articles after applying the inclusion and exclusion criteria*

| Id | Artículo (cita) | País | Modalidad de educación (virtual, presencia, híbrida) | Tipo de motivación (intrínseca o extrínseca) | Tipo de investigación (cuali, cuanti, mixta,etc) | Naturaleza de la población | Asignatura empleada como caso de estudio | Herramientas tecnológicas que emplean | Otras estrategias o tecnológicas empleadas | Hallazgos adicionales dentro de la experiencia gamificada |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Vides, J., Alvarez-Díaz, K. (2023). | España | presencial | Extrínseca | Mixta | 12 estudiantes que fueron los que asistieron a clase (3 mujeres y 9 hombres), entre 21 y 30 años, de 4° de Grado en Economía. | Economía de la Universidad Complutense de Madrid | | Metodología activa: Escape room para convertirse en el Presidente del Banco Central Europeo. Materiales: Salón, boligrafos y papel. (Aprendizaje basada en juegos). | Mejoró la atención sobre las indicaciones de la actividad.<br><br>La consideraron una estrategia dinámica.<br><br>Por la alta competitividad, algunos estudiantes no disfrutaron del juego.<br><br>Generó estrés por el conteo regresivo del tiempo indicado para la actividad.<br><br>Mejoró la comprensión respecto a los contenidos de la asignatura.<br><br>Autonomía en el aprendizaje.<br><br>Motivación de los estudiantes. |
| 2 | Medel-San E, Y. Lisset, Moreno, B. R., & Aguirre, C., E. (2023). | México | Virtual | Intrínseca y Extrínseca | Cuantitativa | 12 estudiantes | Algoritmos y Estructuras de Datos (tercer semestre) en la carrera de Ingeniería en Telecomunicaciones y Redes | | Dinámica de progresión y logros a través de mecánicas como recompensas, que brindan beneficios dependiendo de los logros; desafíos, para las tareas que implicaban un reto; y competición y clasificación, que hace que los estudiantes se esfuercen por verse en los primeros lugares. En cuanto a los componentes, se implementaron las insignias, puntos, desbloqueos, tablas de posición y barras de progreso. (Aprendizaje basado en juegos) | Motivación de los estudiantes.<br><br>Mejora en el interés por la materia. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | López L. H., Félix G. J., Castro S. F., Álvarez R. J., Lizárraga C. L. (2023). | México | | Presencial | Extrínseca | Mixto | No específica | Estudiantes de la Facultad de Informática Mazatlán | No específica | No específica | Mayor participación y compromiso en las actividades académicas.<br><br>Mayor retención y comprensión de información académica.<br><br>Mejora en el rendimiento académico.<br><br>Mejora de la motivación. |
| 4 | Ramos, J. Mora, M. Andrade, E. Zapata, N. (2024). | Ecuador | | Virtual | Extrínseca | Cualitativo de alcance correlacional | 54 estudiantes | Estudiantes de primer semestre de la carrera de Tecnología Superior en Electricidad en asignaturas básicas como Matemática Técnica, Física, Electrotecnia, Comunicación Oral y Escrita, Informática y Realidad Nacional | No específica | No específica | Incrementó el interés de la asignatura.<br><br>Retener y mejorar la información recibida. |
| 5 | Álvarez-Alonso, P., & Echevarría-Bonet, C. (2023). | España | | Híbrida | Intrínseca y extrínseca. | Marco positivista a través de una investigación experimental contemplando a un grupo de control (ING-B y otro de prueba (ING-A) con modelo gamificado. | Fueron 2 cursos (2019-2020 y 2020-2021) con un total de 71 (46) y 58 (23) alumnos, siendo varones el 70% del grupo ING-A y el 60% del grupo ING-B, de edades entre 18 y 20 años con un nivel de competencia digital medio-alto. | Ondas y electromagnetismo | Moodle<br>Actividades individuales: (Office 365, Perusall, power point.<br>Actividades grupales: Kahoot, Flippity. | Complementa con la gamificación con Aprendizaje basado en proyectos a través de empresa ficticia. | Participación activa, compromiso, aprendizaje, colaboración, motivación. |
| 6 | Rodríguez Barboza, J. R., Ávila Sánchez, G. A., Sánchez Aguirre, F. de M., Andrade Díaz, E. M., Méndez Ilizarbe, G. S., Huamaní, R. P., & La Rosa Gallardo, L. A. (2023). | Perú | | Presencial | Intrínseca | Enfoque cuantitativo con diseño correlacional causal, diseño descriptivo no experimental transaccional, positivista. se evaluaron mediante cuestionario 2 variables: la competencia discursiva y la competencia funcional. La técnica de análisis es diagrama de basque. | Una muestra de 90 participantes seleccionados mediante muestreo no probabilístico por conveniencia. Se empleó cuestionario con 25 ítems para evaluar la herramienta quizizz y una rúbrica con 20 ítems para recopilar datos sobre la competencia gramatical | Competencia gramatical en el idioma inglés | Quizziz | No específica | Desempeño académico, colaboración, motivación, participación, retroalimentación constante. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Pérez-López, I. J., Navarro-Maíces, C., & Mora-González, J. (2023). | España | Presencial | Intrínseca | Paradigma interpretativo Metodología cualitativa, con el objetivo de conocer las percepciones del alumnado, a través de una pregunta abierta en Google Drive categorizando las percepciones en 4 categorías principales: gestión emocional, flow, coherencia narrativa, y aprendizaje. | La muestra del grupo en el que se desarrolló estaba formada por 51 estudiantes (36 hombres y 15 mujeres) | Fundamentos de la Educación Física. | Para el breakout de dificultad media.<br><br>Genially, Photopaper web Jigsawplanet Educaplay.<br><br>Para el breakout de dificultad alta: Lockee.fr. Photopaper web Board GamesGeek. | Complementaron la gamificación a través de dos breakouts (aprendizaje basado en juegos) con recursos digitales de apoyo ambientado en la saga de Harry Potter y denominado Harry Potter: el legado de Dumbledore. | Gestión emocional, aprendizaje, resolución de problemas, colaboración, adaptación a nuevas situaciones, flow, motivación. |
| 8 | López-Verdugo, I., Ridao, P., & Reina-Flores, C. (2023). | España | Presencial y virtual | intrínseca | Se combina el análisis cualitativo y cuantitativo de la información (mixto) con una metodología cuasi-experimental<br>. | 447 estudiantes de los Grados de Infantil y Primaria durante el escenario prepandemia (presencial) y durante la pandemia COVID-19 (virtual). La muestra del estudio estuvo compuesta por la totalidad de participantes en la experiencia: 447 estudiantes, 270 en la modalidad presencial y 177 en la modalidad no presencial. El 84,7% de los participantes eran mujeres y el 15,3% hombres. La franja de edad de la muestra abarcaba de los 18-22 años. La diferencia fundamental entre ambos grupos radicó en el desarrollo de la actividad en modalidad presencial para el grupo pre-COVID-19 y en modalidad síncrona online para el grupo COVID-19 | La asignatura Psicología del Desarrollo del Grado en Educación Infantil y del Grado en Educación Primaria | Se utilizó la Blackboard Collaborate Ultra (Plataforma de Enseñanza Virtual). | La actividad de gamificación "¿Quién quiere ser millonario?" constituye una adaptación del famoso juego del mismo nombre con fines pedagógicos (Aprendizaje Basado en Juego) | Colaboración, lúdico, Aprendizaje, gestión emocional, compromiso, motivación. |
| 9 | Velázquez García, L., Longar Blanco, M. del P., & Cedillo Hernández, A. (2024). | México | Presencial | intrínseca | Investigación cuantitativa con enfoque descriptivo. | 125 de Estudiantes del segundo semestre del área de ingeniería, innovación y transformación. Conformados en 6 grupos durante 2 periodos académicos 2021-2022, conformado por 83 hombres y 42 mujeres en edades entre 18 y 29 años del Tec de monterrey. | Análisis de sistemas eléctricos en sistemas ingenieriles | Genially | Gamificación mediante scape room (aprendizaje basado en problemas, aprendizaje basado en juego). La actividad planeo 5 retos disciplinares que al ser resueltos entregan la llave de salida de la sala de escape | Colaboración, resolución de problemas, pensamiento crítico, aprendizaje, compromiso, motivación. |

To begin the analysis of the obtained data, a relational database model was developed, as shown in Figure 1, using the data loaded in Table 1. In it, the multiplicity

relationships between the articles (the Id column within the table, referred to as article id) and each of the analysis categories (the table columns represented as attributes of the articles table and additional tables) were described, followed by the entry of data into an Excel file, in which each tab represented a distinct table of the database model, as can be observed in Table 2.

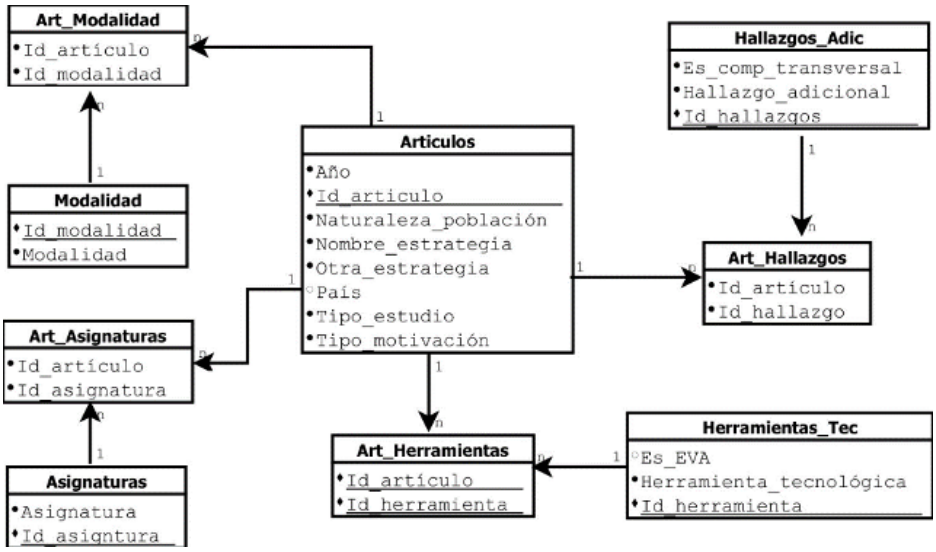
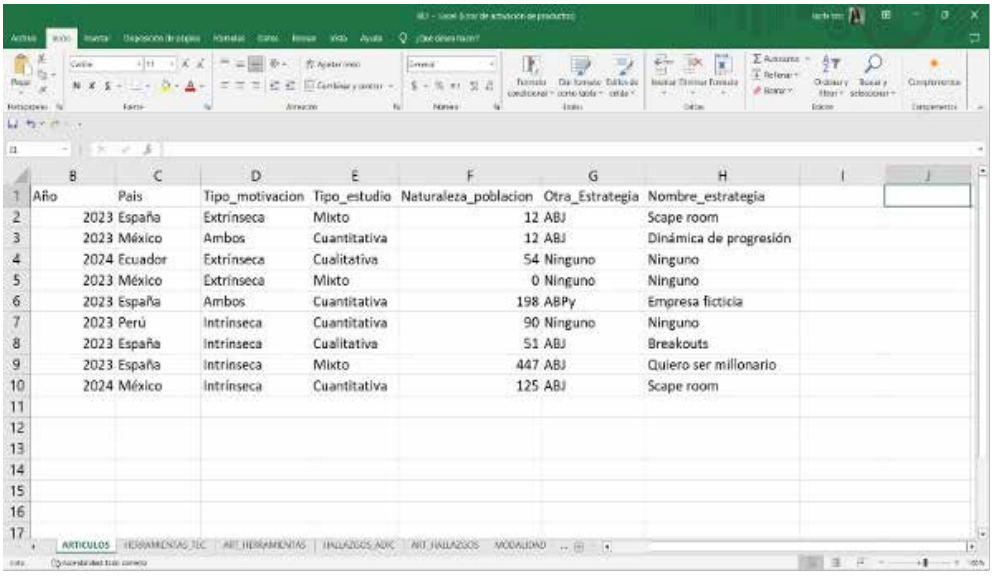



***Figure 1.*** Relational model from Table 1

**Table 2**

*Data from Table 1 uploaded to Excel in different sheets*



| | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Año | Pais | Tipo_motivacion | Tipo_estudio | Naturaleza_poblacion | Otra_Estrategia | Nombre_estrategia | | |
| 2 | 2023 | España | Extrínseca | Mixto | 12 | ABJ | Scape room | | |
| 3 | 2023 | México | Ambos | Cuantitativa | 12 | ABJ | Dinámica de progresión | | |
| 4 | 2024 | Ecuador | Extrínseca | Cualitativa | 54 | Ninguno | Ninguno | | |
| 5 | 2023 | México | Extrínseca | Mixto | 0 | Ninguno | Ninguno | | |
| 6 | 2023 | España | Ambos | Cuantitativa | 198 | ABPy | Empresa ficticia | | |
| 7 | 2023 | Perú | Intrínseca | Cuantitativa | 90 | Ninguno | Ninguno | | |
| 8 | 2023 | España | Intrínseca | Cualitativa | 51 | ABJ | Breakouts | | |
| 9 | 2023 | España | Intrínseca | Mixto | 447 | ABJ | Quiero ser millonario | | |
| 10 | 2024 | México | Intrínseca | Cuantitativa | 125 | ABJ | Scape room | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |
| 17 | | | | | | | | | |

Subsequently, the Excel file was loaded into Power BI to build a dashboard that allowed all charts to be grouped into a single view, one per category of analysis, and advanced filters were applied to understands the behavior of the data based on the selection of any value within any of the categorical variables.

It was thus possible to observe the frequency of articles per category of analysis by selecting a value of interest in the histogram, which generated an effect on the frequencies of the remaining categories within the dashboard for those that met the specified filter. This allowed for the identification of, for example, how many articles reported the generation of intrinsic motivation, extrinsic motivation, or both, as well as those published in 2024, among other insights.

Through this data refinement process, an enriched discussion was established, in which the behavior of the data was described according to each categorical variables, and aspects of interest related to the motivational impact were identified, understood in this research as the effect of the remaining categories according to the type of motivation achieved (intrinsic, extrinsic, or both).

Furthermore, it enabled the exploration of certain data patterns that yielded interesting and conclusive information regarding the subject of study, supported by advanced filters and their propagation across the different categories of analysis, from which the following results were obtained:

- Among the reviewed studies in which gamification was implemented in the teaching-learning process, Spain was identified as the leading country with 44.4% of occurrences, followed by Mexico with 33.3%, while Ecuador and Peru each accounted for 11.1%, as can be observed in Figure 2.

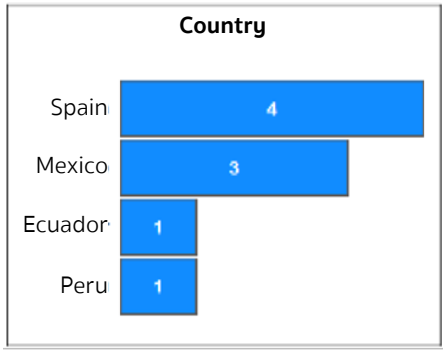



***Figure 2.*** Frequency of items by country

- The predominant *modality* across the reviewed articles was face-to-face instruction, accounting for 55.5%, followed by the virtual modality with 22.2%, in contrast to the hybrid modality and the face-to-face/virtual modality, each representing 11.1%, as can be seen in Figure 3. It is worth noting that this last modality was distinguished from the hybrid one, as it refers to studies that replicated the same educational experience across

two different modalities in order to assess the effects and determine differences; therefore, it was not considered hybrid, given that the hybrid modality alternated between both modalities throughout the educational experience.

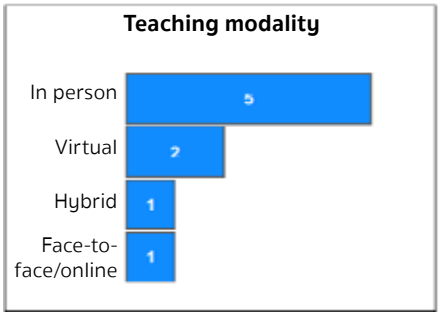



***Figure 3.*** Frequency of articles by teaching modality

- Upon integrating gamification into the teaching-learning process, *the type of motivation* most frequently evidence was intrinsic motivation, as can be observed in Figure 4, accounting for 44.4%, while extrinsic motivation represented 33.3%, followed by 22.2% of studies that generated both types of motivation.

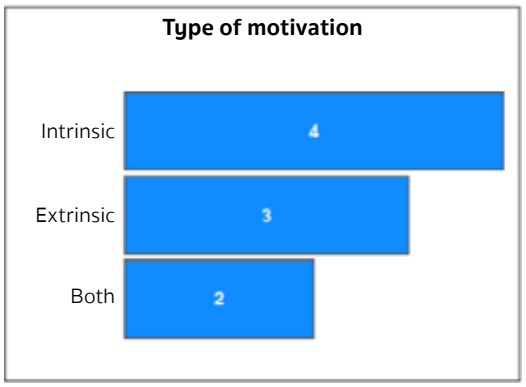



***Figure 4.*** Article Frequency by Motivation Type

- It is noteworthy that 77.7% of the studies consulted for the development of this research were published in 2023, while 22.2% of the articles corresponded to 2024, as can be seen in Figure 5.

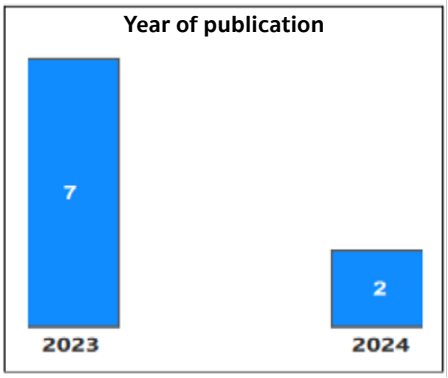



***Figure 5.*** Frequency of articles per year of publication

- The *predominant research approach* was quantitative, accounting for 44.4%, the mixed approach was employed in 33.3% of the reviewed works, and the qualitative approach was applied in 22.2%, as can be observed in Figure 6.

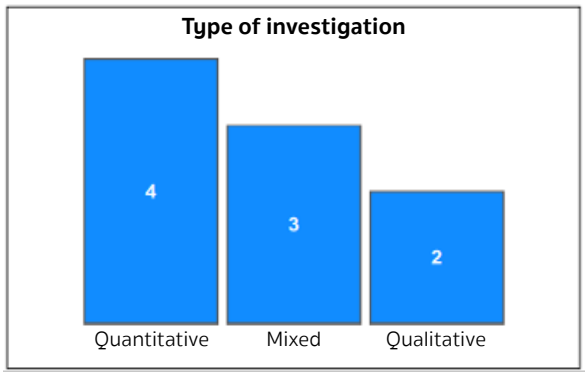



***Figure 6.*** Article Frequency by Research Type

- Regarding the *strategies integrated with gamification*, as can be observed in Figure 7, Game-Based Learning (GBL) was mentioned in 55.5% of the studies, while 33.3% did not integrate any particular strategy into the gamified design. Finally, Project-Based Learning (PBL) predominated with 11.1%.

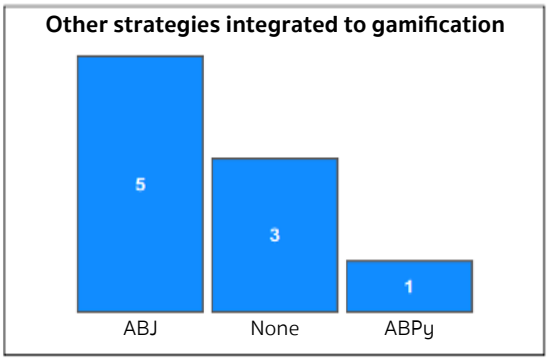



***Figure 7.*** Frequency of articles by other strategies integrated to Gamification

- Among the *subjects* mentioned in which gamification was implemented to fulfill the objectives of the conducted studies, its application was highlighted across a wide variety of disciplines, including Computer Science, Electrical Systems, Physics, Physical Education, Oral and Written Communication, Algorithms and Data Structures, English Grammar Competence, Economics, Psychology, Electrotechnics, Mathematics, and National Reality.

- It was possible to confirm, from the students' perspective, that among the *findings identified* in the reviewed articles, 100% demonstrated a positive impact on motivation, 55.5% evidenced improvements in Learning and Collaboration, 44.4% reported improvements in Engagement, and 33.3% developed Active Participation.

  Content comprehension, Academic performance, Emotional management, Interest in the subject, Improved attention, and Problem-solving were each mentioned in 22.2% of the studies, while 11.1% reported finding such as: Adaptation to new situations, Flow, Stress generation, Ludic engagement, Critical thinking, and Constant feedback. It is noteworthy that 41.17% of these findings corresponded to the achievement of transversal competencies, as can be observed in Figure 8.

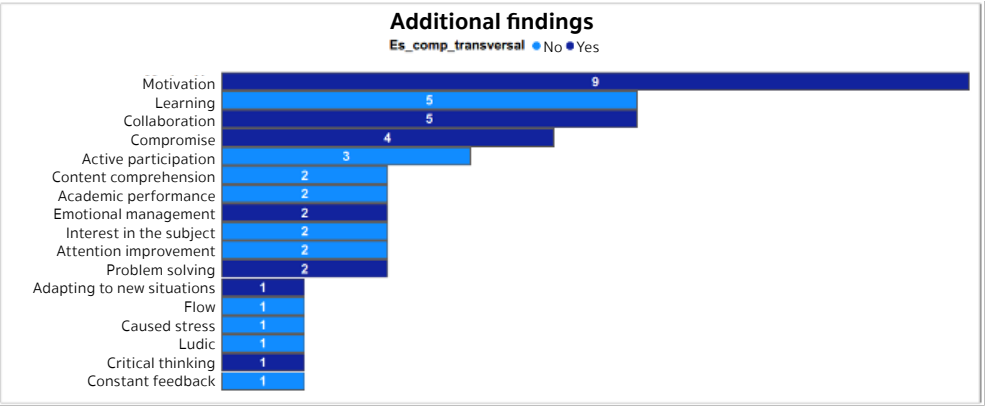



***Figure 8.*** Frequency of articles by Additional Findings and which of them are Transversal Competencies

- Regarding the *gamified activities* employed, these were related to the objective pursued by the activity itself; 33.3% of the articles did not specify the name of the activity, while the "Scape Room" proved to be the strategy with the highest participation rate at 22.2%, followed by "Breakouts", "Progression and Achievement Dynamics", "Fictitious Company" and "Who Wants to Be a Millionaire?" each accounting for 11.1%, as can be observed in Figure 9.

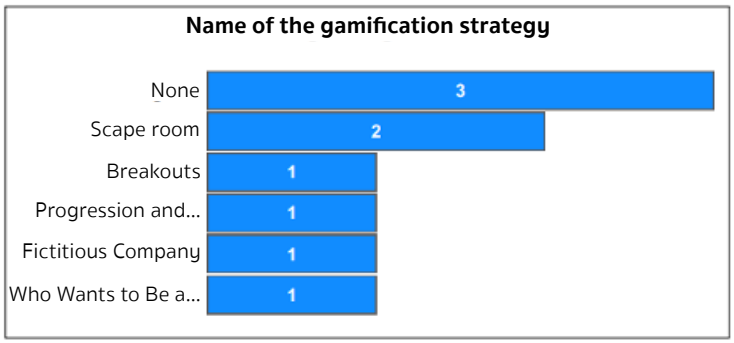



***Figure 9.*** Frequency of articles by Name of the integrated strategy to Gamification

- The *nature of the population* proved diverse, as can be observed in Figure 10; 55% of the studies were conducted with a population of fewer than 100 students, 22.2% involved a population of more than 100 and fewer than 200 students, while 11.1% of the related works involved a population exceeding 400, a percentage shared with those studies that did not specify their population size.

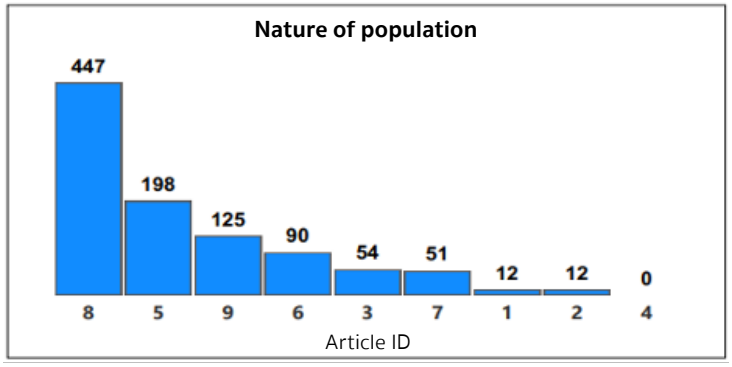



***Figure 10.*** Frequency of articles by Nature of the population

- Finally, regarding the *technological tools* employed, 33.3% did not use any during the development of the gamified activity; of the 66.6% that did, the most frequently used were Genially and Quizizz, with Virtual Teaching/Learning Environments (VLE) accounting for 12.5%; the remaining less frequently used tools can be found in Figure 11.

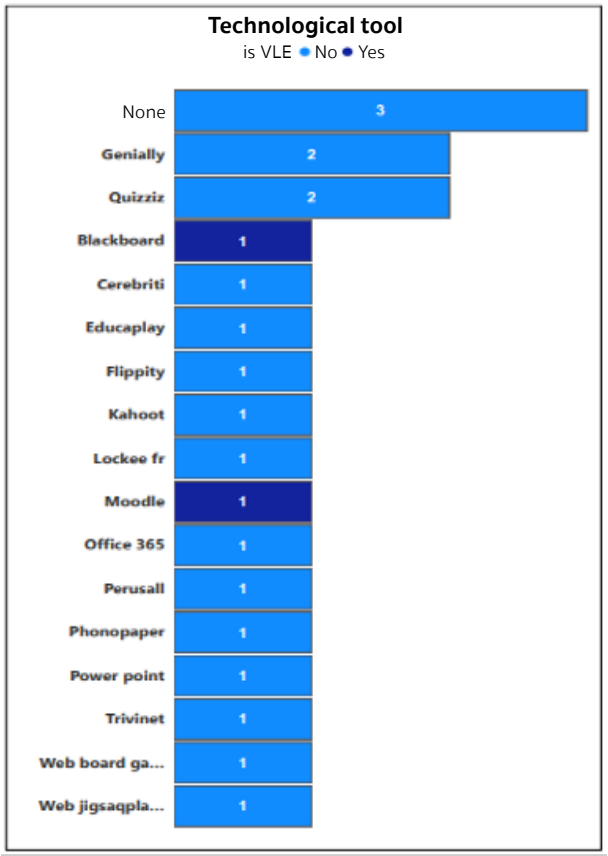



***Figure 11.*** Frequency of articles by technological tool and which of them are Virtual Learning Environments (VLEs)

To address the research question related to the motivational impact on higher education within the Spanish-speaking community, the approach involved relating said impact to the behavior of the type of motivation evidenced (intrinsic, extrinsic, or both) with respect to the remaining categories of analysis, from which the following was obtained:

- Regarding *intrinsic motivation* achieved in relation to the remaining categories, a higher percentage was observed in publications from Spain; the predominant teaching modality was face-to-face instruction, with the majority carried out in 2023.

  Regarding the type of research in which this motivation has been evidenced, the quantitative approach stood out, with Game-Based Learning being the strategy integrates into gamification.

  The studies corresponding to intrinsic motivation have confirmed it in populations ranging from more than 50 students up to a maximum of 447, with Genially being the most frequently employed tool. As for the additional findings observed, the majority of students confirmed having acquired: Collaboration, Learning, Engagement, Emotional management, and Problem-solving skills, among others, which can be identifies in Figure 12.

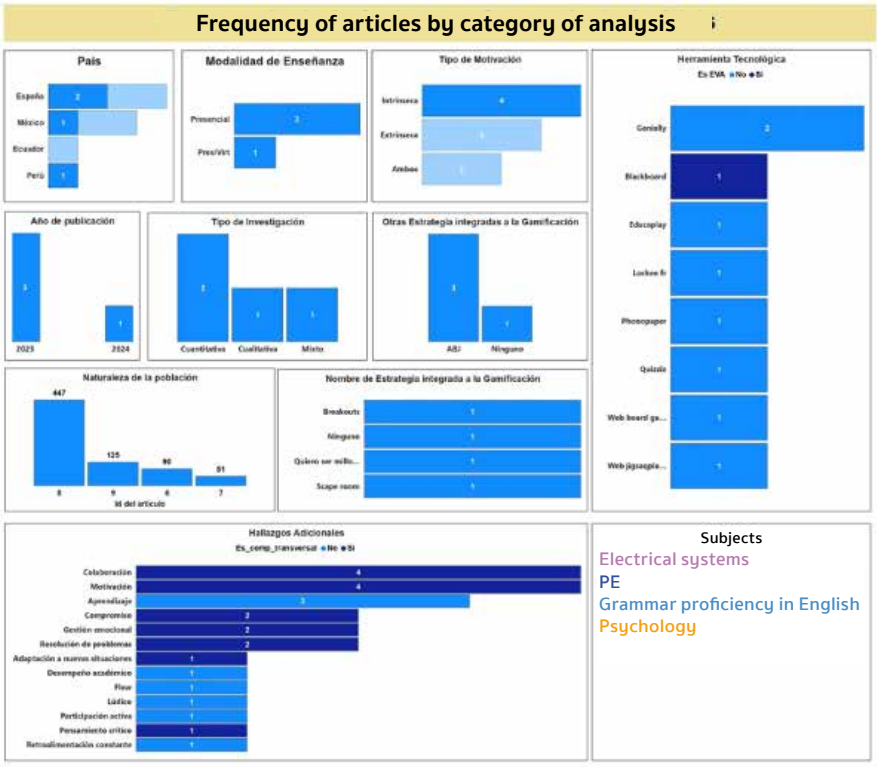



***Figure 12.*** Intrinsic Motivation with respect to the rest of the categories

- The results evidenced from the type of extrinsic motivation in relation to the remaining categories indicated an equal proportion of studies across Spain, Mexico, and Ecuador, where the predominant teaching modality was face-to-face instruction, while the year of publication was 2023.

  The predominant research approach was mixed, without the integration of additional strategies into gamification, with only one study noted in which Game-Based Learning was employed; the nature of the population indicated that the studies were conducted with groups of 12 and 54 students, with the Scape Room also incorporated as a strategy integrated into gamification.

  Regarding the technological tools, Cerebriti, Quizizz, and Trivinet were mentioned. Finally, this type of motivation yielded additional findings such as: *Engagement, Content comprehension, Learning*, among others, which can be found in Figure 13.

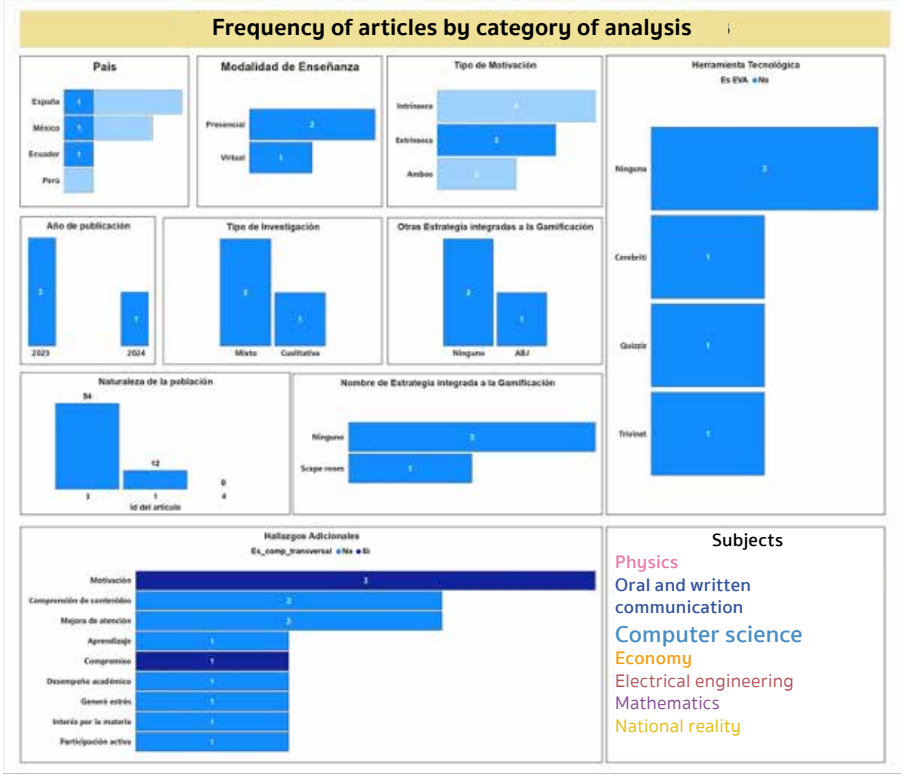



***Figure 13.*** Extrinsic Motivation with respect to the rest of the categories

- Upon analyzing the studies in which students reported having achieved both types of motivation, Intrinsic and Extrinsic, it was observed that these were present in publications developed in Spain and Mexico in 2023, where the teaching modalities employed were face-to-face and hybrid instruction.

Regarding the type of research that evidenced both types of motivation, the quantitative approach was observed, with Game-Based Learning and Project-Based Learning being the strategies integrated into gamification.

The studies corresponding to both types of motivation were confirmed in population of 12 and 198 students, with Flippity, Kahoot, Moodle, Office 365, Perusall, and PowerPoint being the tools employed. As additional finding, the majority of students confirmed having achieved: *Learning, Collaboration, Engagement, Interest in the subject matter,* and *Active Participation*, as can be observed in Figure 14.

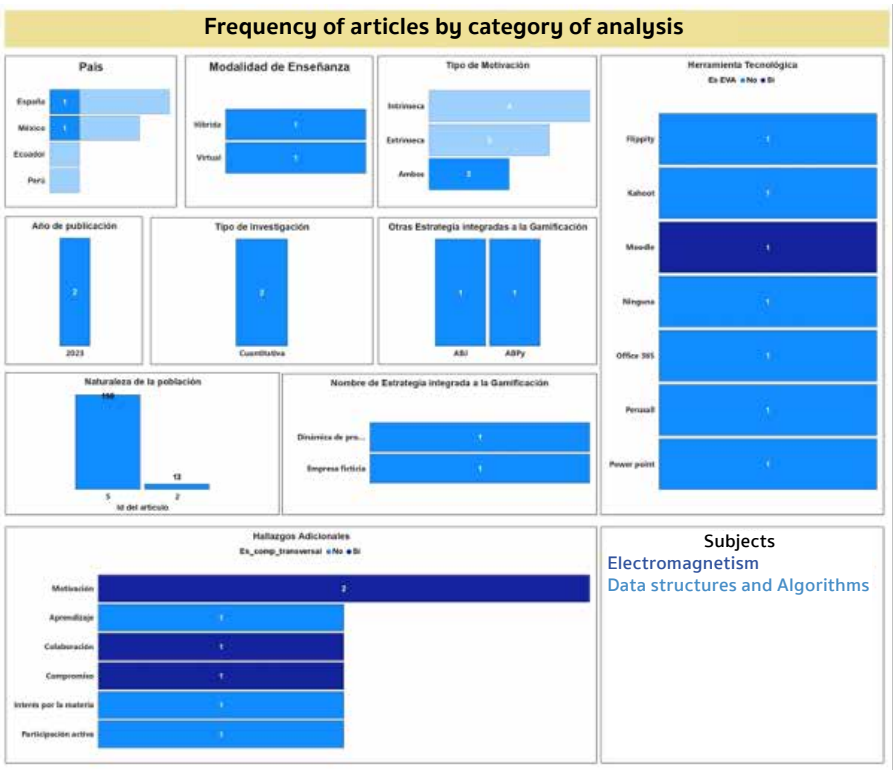



***Figure 14.*** Intrinsic and Extrinsic Motivation with respect to the rest of the categories

Likewise, in addressing the second research question related to the procedure or tool for data analysis, a methodology was contributed for mapping the data from Table 1, drawing on foundational knowledge of databases to generate a relational model that considered the multiplicity relationships among them. Subsequently, the data were transferred into Excel and then read by the Power BI tool, from which the dashboard with the resulting histograms was constructed, employing filters that propagated across the different categories of analysis.

## CONCLUSIONS

Through the appropriate definition of the inclusion and exclusion criteria, the identification and analysis of 9 research articles from the Mendeley repository was achieved, thereby allowing the following assertions to be made regarding the efforts carried out in recent years (2023-2024) by the Spanish-speaking community in employing gamification within the educational process.

Spain is the country of origin with the highest number of recent publications; the articles were most frequently published in 2023; the variation in the nature of the population ranged from 12 to 447 participants; the tools most frequently employed by the community to build gamified resources were Genially and Quizizz, corroborating what was noted by Vergara Rodríguez et al. (2019), who indicate that these tool are popular due to their ludic approach, fostering participation through the interactive and creative activities that can be developed with them.

Moreover, it was demonstrated that gamification has been applied across a diverse range of disciplines and professional profiles, thereby validating that this educational strategy can be employed in any field of professional development within higher education, which is confirmed by Ortiz et al. (2018), cited by Caponetto (2014), who regard gamification as a learning tool that can be employed across different subjects for the development of attitudes, collaborative behaviors, and autonomous study.

Furthermore, Game-Based Learning using the *Scape Room* represented the most frequently employed option as a teaching-learning tool linked to gamification, which confirms the assertions made by Piñero Charlo (2019), who notes that a strong interest has emerged in the educational sphere for developing this type of strategy, in addition to what is emphasized by Rodríguez-Oroz et al. (2019), who highlight the compatibility of gamification with other teaching strategies.

Nevertheless, gamification has identified a series of challenges and complexities in its design, according to the perspective of the participants in the related works analyzed. Among them, Vides and Alvarez-Diaz (2023) noted that during their educational experience, students reported feeling stressed when working on timed activities, which may obscure the true intention of learning through play. In addition, Álvarez-Alonso and Echeverria-Bonet (2023) highlighted the importance of taking group size into account when implementing a gamified experience, as the feedback process can be demanding and exhausting; therefore, the design of the experience must consider the effects that the frequent use of time pressure and even group size may produce.

For this reason, future work is expected to address this study by considering a search and selection of articles exclusively in English, in order to verify whether the findings remain consistent or whether new learning strategies or concepts emerge that are related to the contexts of use within communities where English is the native language.

Likewise, among the categorical variables examined to analyze the motivational impact of gamification in higher education, the following was found: the preferred teaching modality for gamification has been face-to-face instruction: the most frequently reported type of motivation was intrinsic, as supported by Lomba et al. (2021), who assert that gamification in higher education has been characterized by achieving this type of motivation; and the research approaches most frequently employed to demonstrate improvements in motivation were quantitative in nature.

Besides, the concept of flow was mentioned by the students and refers to a state of complete concentration on the activity while maintaining active participation in it (García Lázaro, 2019). This invites consideration of this variable as a relevant aspect of study when implementing gamification.

Addressing the second objective of this research, the data analysis procedure suggested alongside the Power BI tool proved useful in optimizing the time required for data preparation and descriptive analysis, as its filtering capability streamlines the counting of value occurrences and, consequently, aids in the formulation of assumptions and data-driven decision-making.

Finally, valuable finding derived from the impact of gamification was the identification, within student perceptions, of impressions expressed during the educational experience, such as: learning, active participation, content comprehension, academic performance, interest in the subject matter, improved attention, and flow; as well as aspects related to varying degrees of transversal competency or *soft skill* development, as listed by Galdeano Bienzobas and Valiente Barderas (2010), including: motivation, collaboration, engagement, emotional management, problem-solving, adaptation to new situations, and critical thinking. This demonstrates, according to Bassi, Busso, Urzua, and Vargas (2012), as cited in Gontero and Albornoz (2019), the capacity of gamification to develop in students these life skills that are in high demand in today's labor market.

This allowed for the assertion that gamification is not only an educational strategy that motivates students to generate their own knowledge, but that, with the support of the Power BI analysis tool, it was evidenced as a powerful alternative for developing the transversal competencies demanded by the global villages.

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# Osmotic dehydration of *Mangifera indica* L. var. Oro with high sensory quality

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*— Abstract—*

*Mangifera indica* L. var. Oro is a crop of considerable importance in Mexico; however, its limited shelf life leads to significant postharvest losses. In this context, osmotic dehydration emerges as a viable technological alternative to extend the shelf life of mangos. The objective of this work was to evaluate the effects of temperature (40 and 60°C), sucrose content (40 and 60 °Brix), and vacuum pulse (5 and 15 psi) on water loss (WL) and solid gain (SG) during the osmotic drying of mango slices and to determine the degree of acceptance of osmodehydrated mango. WL and SG were calculated by weight difference, and the degree of acceptance was determined by a 9-point structured hedonic test. Azuara's equation was used to model the water loss and solid gain. Mango osmodehydrated at 50 °Brix, 60°C and 15 psi had the best degree of acceptance (7.38). To optimize multiple response variables through the application of a mathematical model, conditions of 53 °Brix, 51°C, and a vacuum pulse of 7.65 psi can be employed to maximize water loss and minimize sucrose gain. However, owing to the lack of statistical significance of the vacuum pulse and for industrial purposes, conditions of 50 °Brix at 50°C could be used without the application of a vacuum pulse. These latter conditions could be applied for industrial purposes to obtain a mango product with a longer shelf life than that of fresh mango while maintaining good sensory acceptance.

**Keywords:**
*Water loss; impregnation; mangoes; osmodehydration.*

In Mexico, annual mango (*Mangifera indica*) production in 2023 exceeded two million tons, with Sinaloa, Guerrero, Nayarit, Chiapas, and Oaxaca being the leading producing states (Smattcom, 2024). Although nearly 20% of production in 2017 was destined for export to the United States and other countries (SAGARPA, 2017), the remainder was sold domestically as fresh fruit or processed into juices, nectars, and dried products. The Tommy Atkins, Ataulfo, and Kent varieties have been extensively studied; however, little scientific and technological information is available on the Oro variety, making it important to generate such information.

In this context, dehydration is a process that removes water to produce products with low moisture content, which results in a longer shelf life than that of a fresh product (Kilic et al., 2023). However, the physicochemical and sensory properties of the product can vary drastically. Kilic et al. (2023) reported a review of the different drying methods. In this study, the authors note that hot-air drying yields products with a long shelf life, but the sensory and nutritional characteristics of the products may be significantly reduced. These authors also reported that other methods exist, such as osmotic dehydration (OD), which yields foods with better sensory characteristics than those produced by conventional dehydration (Kilic et al., 2023). For this reason, osmotic dehydration is a widely used process for extending the shelf life of foods (Marie et al., 2025).

OD is a processing technique that involves immersing food matrices in a solution with a high concentration of solute (Asghari et al., 2024) and consists of three stages: i) the transfer of water from the product to the hypertonic solution; ii) the migration of the osmotic solute into the product; and iii) the leaching of natural matrix components (sugars, acids, minerals, and vitamins) into the hypertonic solution (Huerta-Vera et al., 2024). Many researchers have studied the OD, finding that the solute concentration (Arias et al., 2017), the temperature of the osmotic solution (Arias et al., 2017), the pressure at which the process is carried out (Vinod et al., 2024; Staniszewska et al., 2024), the syrup-to-fruit ratio (Vinod et al., 2024) and the processing time (Vinod et al., 2024) influence water loss and solute again. OD has been used for the preservation of different fruits, including mango. Arias et al. (2017) studied the mass transfer kinetics during the osmotic dehydration of mango (*Mangifera indica* L.) var. Tommy Atkins in sucrose solutions (45–60° Brix) at different temperatures (20, 35 and 50°C) for 6 h. However, these authors used a syrup-to-fruit ratio (mL:g) of 3:1, which could have diluted the solution after the first hour of processing, causing changes in the concentration of the osmotic solution such that mass transfer was not constant.

Response surface methodology has been used to optimize OD processes in fruits, as reported by Tsopwo Zena and Jiokap Nono (2024). However, the coefficients of determination obtained through multiple regression do not always yield satisfactory levels of fit. Consequently, various researchers have turned to alternative mathematical models, such as those proposed by Azuara, Peleg, and Weibull, which have proven more effective at describing the kinetics of water loss

and solute gain during OD, as well as at estimating the effective diffusivity of these phenomena (Sulistyawati et al., 2020). Determining the effective diffusivities of water and solutes during osmotic dehydration allows more accurate predictions of changes in moisture and solids content in the treated product and helps optimize process conditions.

Although there are numerous publications on the OD of mango, to our knowledge, few studies have been published on the Oro variety. Therefore, in this study, the effects of the sucrose concentration (40 and 60 °Brix) and temperature (40 and 60°C) of the osmotic solution, as well as the application of a vacuum pulse (5 and 15 psi), on water loss (WL) and solute gain (SG) in mango (*Mangifera indica* var. Oro) and the degree of acceptance of the osmodehydrated mango were determined. Furthermore, WL and SG were modeled to calculate the effective diffusivities of water and sucrose during osmotic dehydration.

## MATERIALS AND METHODS

### *Osmotic dehydration*

The fruits of *Mangifera indica* var. Oro were obtained from a local supermarket in the city of Tuxtla Gutiérrez, Chiapas, Mexico. Mangoes were washed and peeled by hand and cut into rectangular parallelepipeds 30 mm long, 18 mm wide and 10 mm thick. The pieces were immersed in a commercial sucrose solution at a controlled concentration and temperature. The methodology used for the osmotic dehydration of mango is shown in Figure 1.

Approximately 100 g of mango was immersed in 1 kg of osmotic solution at a controlled temperature in an Erlenmeyer flask equipped with a magnetic stirrer and a stopper containing a vacuum tube, as reported by Grajales-Lagunes et al. (2019). This 1:10 (w/w) fruit-to-osmotic solution ratio was used to prevent dilution of the osmotic solution (Antonio et al., 2008). During the first ten minutes of the OD, a vacuum pulse (VP) was applied, and atmospheric pressure was subsequently restored, as described by Grajales-Lagunes et al. (2019). Mango samples were collected at 0, 10, and 360 min; they were then washed with distilled water to remove surface sucrose and dried with absorbent paper. The samples were weighed on an analytical balance (Ohaus, New Jersey, USA) (sensitivity of 0.0001 g), and the moisture content was determined in quintuplicate in a vacuum oven at 60°C until a constant weight was reached.

The WL and SG were calculated using equations 1 and 2:

$$WL = \frac{W_o X_o - W_t X_t}{DM_o} \qquad (1)$$

$$SG = \frac{W_o DM_o - W_t DM_t}{DM_o} \qquad (2)$$

where $W_o$ is the weight of the mango (g), $X_o$ is the moisture content (g $g^{-1}$), $DM_o$ is the dry matter fraction (g $g^{-1}$) at the start of osmotic drying, and $W_t$, $X_t$ and $DM_t$ lare the corresponding values during osmotic drying.

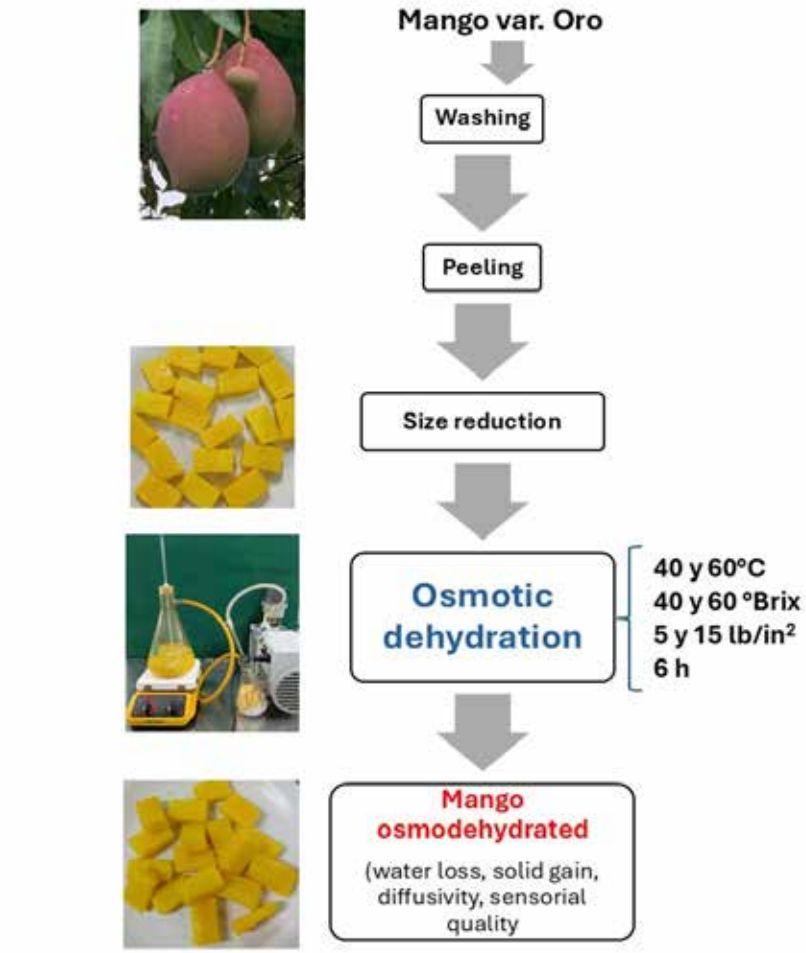


***Figure 1.*** Methodology used for the osmotic dehydration of mangoes

*Experimental design and statistical analysis*

A Box–Behnken response surface methodology design was used, with each treatment performed in triplicate and three additional replicates at the center point, resulting in a total of 13 treatments (Table 1). The effects of temperature (40 and 60°C), sucrose content (40 and 60 °Brix) and vacuum pulse (5 and 15 psi) on the WL and SG of mango pieces during osmotic dehydration were evaluated. The results were analyzed using Statgraphics Centurion XV software (StatPoint Technologies, Inc., Virginia, USA). WL and SG were modeled through response surface methodology (Tsopwo Zena & Jiokap Nono, 2024) with the help of equation 3:

$$Y=\beta_{k0}+\sum_{i=1}^{3}\beta_{ki}X_i+\sum_{i=1}^{3}\beta_{kii}X_i^2+\sum_{i=1}^{2}\sum_{j=i+1}^{3}\beta_{kij}X_iX_j \qquad (03)$$

Where Y denotes the solid gains or water loss; $\beta_{ko}$, $\beta_{ki}$, $\beta_{kii}$ and $\beta_{kij}$ are the model coefficients; and $X_i$ y $X_j$ are the uncoded independent variables. The $R^2$ for each equation was calculated and reported.

In addition, WL (PA) and SG (GS) were adjusted with the model reported by Azuara (Sulistyawati et al. 2020):

$$\frac{PA}{PA_{eq}}=\frac{s_{PA}\,t}{(1-s_{PA}\,t)} \quad \text{and} \quad \frac{GS}{GS_{eq}}=\frac{s_{GS}\,t}{(1-s_{GS}\,t)} \qquad (4)$$

where $PA_{eq}$ and $GS_{eq}$ are WL and SG after 6 hours, respectively; $s_{PA}$ and $s_{GS}$ are the empirical constants to be identified; and t is time in hours. The water loss and solid gain at equilibrium are represented, and $s_{PA}$ and $s_{GS}$ are the empirical constants to be determined. These constants were calculated using the average values of osmotic dehydration kinetics via the revised simplex method (Jarry-Bolduc & Planiden, 2025) by minimizing the objective functions represented in Equation 5.

The values of $\sigma_{PA}$ y $\sigma_{GS}$ were calculated for each treatment:

$$\sigma_{PA}=\sqrt{\frac{\sum_{i=1}^{n}(PA_{exp}-PA_{sim})^2}{n}} \quad \text{and} \quad \sigma_{GS}=\sqrt{\frac{\sum_{i=1}^{n}(GS_{exp}-GS_{sim})^2}{n}} \qquad (5)$$

Where n represents the total number of experimental data points and the subscripts exp and sim denote the experimental and simulated values, respectively.

The diffusivity of water and sucrose (*Di*), as a function of s, was calculated by equation 6:

$$Di=\frac{4L^2}{\pi^2 t}ln\left\{\frac{\pi^2}{8}\left[1-\frac{s_i}{1+s_i t}\right]-\frac{1}{9}\left[\frac{\pi^2}{8}\left[1-\frac{s_i t}{1+s_i t}\right]^9\right]\right\} \qquad (6)$$

Where L corresponds to half the thickness of the sample in millimeters, t is the time in seconds and $s_i$ is the constant to be identified for WL and SG.

### *Sensory analysis*

After six hours of osmotic drying, the mango samples were analyzed using a 9-point structured hedonic test by 100 untrained judges (D'Aquino de los Santos et al., 2022). Sensory analyses of the 12 treatments were conducted in independent sessions. In each sensory evaluation session, each judge rated the overall acceptability of the mango samples corresponding to the four treatments to avoid sensory fatigue. The

sample consisted of 100 untrained judges (46 men and 54 women) between the ages of 18 and 25. All participants were informed that they could withdraw from the study at any time if they wished. The results were analyzed using Tukey's test, with a significance level of $p < 0.05$.

## RESULTS AND DISCUSSION

### *Water loss and solid gain*

The results revealed that the mango loses water and becomes impregnated with sucrose during OD (Table 1). These results are consistent with those reported by Sulistyawati et al. (2020) and Tsopwo Zena and Jiokap Nono (2024).

After 10 minutes of treatment, water loss ranged from 0.0436 to 0.1510 g water/g fresh fruit, whereas solid gain ranged from 0.0012 to 0.0535 g of sucrose/g of fresh fruit. In contrast, after 360 minutes of treatment, water loss varied from 0.3188 to 0.5920 g of water/g of fresh fruit, and solid gain ranged from 0.0724 to 0.1541 g of sucrose/g of fresh fruit.

The sucrose concentration and the temperature of the solution significantly affected water loss (Table 2). These results are consistent with those reported by Sablani and Rahman (2003), who reported that water loss increases with increasing temperature and concentration. Similarly, Zapata Montoya and Montoya Rodas (2012) reported that solution temperature affects mass transfer during the osmotic dehydration of Tommy Atkins mango. However, the vacuum pulse had no statistically significant effect. This was likely due to the low porosity of the mango, which prevented the exchange of solutes from the solution into the fruit, as reported by Mújica-Paz et al. (2003).

**Table 1**
*Water loss (WL) and solid gain (SG) of mango during the osmotic dehydration of Mangifera indica var. Oro under different processing conditions*

| C (°Brix) | T (°C) | Vacuum pulse (psi) | Time | | | |
|---|---|---|---|---|---|---|
| | | | 10 min | | 360 min | |
| | | | WL (g/g) | SG (g/g) | WL (g/g) | SG (g/g) |
| 60 | 40 | 10 | 0.0966+0.0501 | 0.0301+0.0367 | 0.5283+0.0350 | 0.1157+0.0446 |
| 60 | 60 | 10 | 0.0991+0.0471 | 0.0280+0.0136 | 0.5546+0.0626 | 0.1309+0.0503 |
| 40 | 40 | 10 | 0.0436+0.0059 | 0.0075+0.0051 | 0.3188+0.1025 | 0.0761+0.0120 |
| 50 | 60 | 5 | 0.1374+0.0565 | 0.0357+0.0048 | 0.5659+0.0350 | 0.1079+0.0179 |
| 50 | 50 | 10 | 0.1510+0.0575 | 0.0012+0.0069 | 0.5366+0.0713 | 0.0767+0.0274 |
| 40 | 50 | 15 | 0.0729+0.0288 | 0.0299+0.0052 | 0.3749+0.0725 | 0.141+0.0357 |
| 40 | 50 | 5 | 0.0723+0.0202 | 0.0147+0.0158 | 0.4076+0.0310 | 0.0887+0.0241 |
| 40 | 60 | 10 | 0.0773+0.0272 | 0.0382+0.0226 | 0.4544+0.0305 | 0.1363+0.0082 |
| 50 | 60 | 15 | 0.1075+0.0445 | 0.0535+0.0082 | 0.5160+0.0536 | 0.1541+0.0332 |
| 50 | 40 | 15 | 0.0530+0.0054 | 0.0036+0.0124 | 0.4574+0.0347 | 0.0724+0.0346 |
| 50 | 40 | 5 | 0.0713+0.0349 | 0.0193+0.0078 | 0.4297+0.0823 | 0.0921+0.0412 |
| 60 | 50 | 5 | 0.1134+0.0123 | 0.0254+0.0104 | 0.5920+0.0414 | 0.0847+0.0344 |
| 60 | 50 | 15 | 0.1046+0.0272 | 0.0263+0.0170 | 0.5746+0.0636 | 0.1119+0.0743 |

C= Sucrose content, T= Temperature of the osmotic solution.

**Table 2**
*Effects of vacuum pulse, temperature and sucrose content in an osmotic solution on water loss (WL) and solid gain (SG) in mangos*

| **Factor** | **Value - p** | |
|---|---|---|
| | **WL** | **SG** |
| Vacuum pulse (psi) | 0.8328 | 0.1875 |
| Solution temperature (°C) | 0.0018* | 0.0115* |
| Sucrose content (° Brix) | 0.0000* | 0.3836 |

* denotes a statistically significant difference.

WL and SG increased with increasing temperature of the osmotic solution after 6 hours of drying, but this effect was not meaningful during the first 10 minutes (Figure 2). The application of a vacuum pulse did not affect the WL or SG (Figure 2c). The results of this study differ from those reported by Lin et al. (2016) and Sulistyawati et al. (2018), who reported that the application of vacuum pulses influenced mass transfer during the osmotic dehydration of mango. This discrepancy could be attributed, at least in part, to methodological differences in the way vacuum was

applied. In particular, Sulistyawati et al. (2018) reported that a vacuum pulse had a negative effect on water loss but promoted solid gain. In contrast, Lin et al. (2016) demonstrated that the application of vacuum facilitated both water loss and solid incorporation. These differences suggest that the impact of vacuum on mass transfer mechanisms may depend critically on specific operational variables, such as the duration, intensity, and sequence of the applied pulses, as well as on the physicochemical characteristics of the food system being treated.

Analysis of variance revealed that temperature had a significant effect on the SG (Table 2). This is clearly illustrated in Figure 2d, where an increase in temperature leads to an increase in solid gain. These results are consistent with those reported by Sablani and Rahman (2003), who reported that solid gain increases with increasing solution temperature. However, these results differ from those reported by Gomes-Corrêa et al. (2016), who demonstrated that a vacuum pulse reduced solid gain during tomato OD. These discrepancies could be explained by differences in the composition and structure of mangoes and tomatoes.

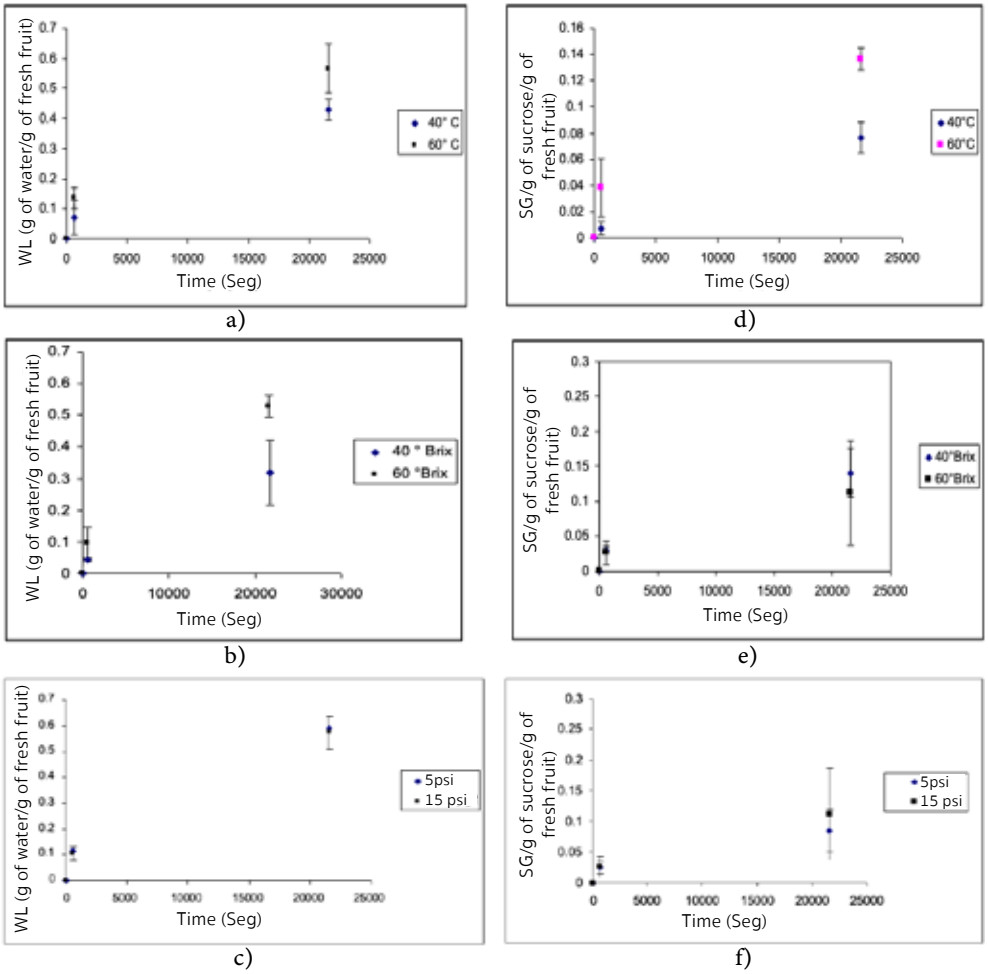


***Figure 2.*** Effects of the osmotic solution temperature (a, c), sucrose concentration (b, d), and vacuum pulse (c, e) on water loss and solid gain during the osmotic dehydration of mangoes

*Sensory analysis*

The mango's WL and SG during the OD may have influenced the overall acceptance of the product. In this context, the results of the hedonic test revealed that processing conditions significantly affected the overall acceptance of the "Oro" mango (Table 3). The samples that received the highest and lowest levels of acceptance from the untrained judges were sample I, processed at 50 °Brix, 60°C, and 15 psi, and sample C, processed at 40 °Brix, 40°C, and 10 psi, respectively. Sample I received a rating of 7.38 ("like moderately"), while sample C received a rating of 6.01 ("like slightly"). Notably, all the samples received an overall acceptance rating (on the verbal scale) higher than "like", leading us to conclude that any of the processing conditions could be used for industrial purposes.

Few studies have reported on the level of acceptance of osmodehydrated mangoes. In this context, the use of osmotic dehydration as a pretreatment for mangoes prior to hot-air drying improved their sensory properties, as reported by Sanjinez-Argandoña et al. (2017). In addition, Zapata Montoya and Montoya Rodas (2012) reported that the sensory analysis conducted on mango cv. Tommy Atkins pieces showed 100% acceptance for samples of mango slices osmotically dehydrated at 45°C with 3% citric acid in the osmotic solution. However, unlike this study, these authors did not specify the test used. Nevertheless, these values are higher than those reported by Bernardi et al. (2009) for osmotically dehydrated mango, with maximum scores of 5.69 on the nine-point hedonic test.

**Table 3**
*Overall acceptance of mango after six hours of osmotic drying*

| Treatment | Overall acceptance |
|---|---|
| I.50 °Brix, 60°C, 15 psi | 7.38 a |
| F.40°Brix, 50°C, 15 psi | 7.16 ab |
| L.60 °Brix, 50°C, 5 psi | 7.16 ab |
| H.40 °Brix, 60°C, 10 psi | 7.12 ab |
| B.60°Brix, 60°C, 10 psi | 7.01 abc |
| D.50°Brix, 60°C, 5 psi | 6.98 abc |
| E.50°Brix, 50°C, 10 psi | 6.67 bcd |
| M.60 °Brix, 50°C, 15 psi | 6.52 bcde |
| G.40 °Brix, 50°C, 5 psi | 6.45 cde |
| A.60°Brix, 40°C, 10 psi | 6.41 cde |
| K.50 °Brix, 40°C, 5 psi | 6.39 cde |
| J.50 °Brix, 40°C, 15 psi | 6.19 de |
| C.40°Brix, 40°C, 10 psi | 6.01 e |
| Tukey | 0.65 |

Based on a careful assessment of the costs associated with the osmotic dehydration process for mangoes and considering the overall level of acceptance achieved by the products obtained in this study, we propose the implementation of more efficient operating conditions: lower temperatures, lower sucrose concentrations, and the omission of the vacuum pulse. This strategy would allow for the production of sensorially acceptable products while helping to reduce production costs. In particular, the reduction in temperature and sucrose concentration, along with the elimination of vacuum treatment, results in lower energy and input requirements. However, to validate the feasibility of this proposal, it is essential to conduct a technical–economic study that quantifies the potential benefits and assesses its applicability on an industrial scale.

*Optimization of the osmotic dehydration process*

To optimize the OD process for mangoes, response surface methodology was used; the goal was to maximize water loss and minimize solid gain, with the aim of producing a product with the highest level of consumer acceptance.

Our initial approach involved the use of multiple regression analysis in conjunction with response surface methodology. Table 4 presents the models that explain water loss and solid gain in mangoes after 6 hours of osmotic dehydration. Notably, the coefficients of determination (R2) of the models are not close to one, indicating that mass transfer (water and sucrose) cannot be fully explained by this multiple regression model.

**Table 4**
*Mathematical models for water loss (WL) and solid gain (SG) in mangoes after 6 hours of osmotic drying using response surface methodology*

| Mathematical model | $R^2$ |
|---|---|
| $PA = -2.54 + 0.054\ A + 0.052\ B + 0.020\ C - 0.00032\ A^2 - 0.00027\ AB + 0.0000065\ AC - 0.0003\ B^2 - 0.0004\ BC - 0.00014\ C^2$ | 0.63 |
| $GS = 0.583 - 0.0088\ A - 0.011\ B - 0.0135\ C + 0.00015\ A^2 - 0.00011\ AB - 0.00013\ AC + 0.00016\ B^2 + 0.00033\ BC + 0.0003\ C^2$ | 0.30 |

A=sucrose concentration (° Brix), B= solution temperature (°C) y C= vacuum pulse (psi), $R^2$ is the coefficient of determination.

However, the response surface methodology showed that the maximum water loss achievable is obtained using a syrup concentration of 60 °Brix, a temperature of 56.67°C, and a pressure of 5 psi. This water loss, as simulated by the model, corresponds to 0.5912 g of water/g of fresh fruit. Furthermore, using response surface methodology, it was found that the minimum solid gain achievable is obtained by using an osmotic solution concentration of 47.08 °Brix, a temperature of 43.73°C,

and a pressure of 8.42 psi. This solid gain, as simulated by the model, corresponds to 0.0745 g of water/g of fresh fruit.

Zapata Montoya and Montoya Rodas (2012) reported the same trend regarding the coefficients of determination for the mathematical models of osmotic dehydration in Tommy Atkins mangoes. These authors reported a coefficient of determination for water loss of 0.99, but for solid gain, it was 0.30, with solid gain showing the greatest variability. This may be because, during the OD process, not only does sucrose enter the fruit, but other sugars and soluble compounds—such as organic acids—are also leached from the fruit into the solution. In addition, the difference may be due to the composition and structure of the mango varieties used.

When the results of the optimal treatment—designed to maximize water loss and minimize solid gain—were compared with those of the best treatment on the basis of sensory evaluation, we observed that the WL and SG values for the treatments at 60 °Brix, 50°C, and 5 psi were 0.5920 and 0.00847 g/g fresh fruit, respectively. This treatment was similar to the optimal treatment, which yielded WL and SG concentrations of 0.5938 and 0.0745 g/g of fresh fruit, respectively. Although the optimal treatments were identified using response surface methodology, the model needs to be improved because of the low coefficient of determination (R2); thus, we applied the Azuara model.

### *Azuara model*

Azuara's model provided a better fit for the results than the equations obtained using response surface methodology did. The sPA (WL) and sGS (SG) parameters (Table 5) were identified for each of the kinetics using Equations 4, 5, and 6, and the values ranged from 1.6553 to 3.1662 for water loss and from 1.2026 to 4.9296 for solid gain.

The average effective diffusivity (Di), which is calculated using Equation 6, shows that for water, the values ranged from $4.2516 \times 10^{-10}$ to $0.7039 \times 10^{-10}$ m²/s, whereas for solid gain, Di changed from $3.5737 \times 10^{-10}$ to $0.5317 \times 10^{-10}$ m²/s. These values are statistically equivalent, so we calculated averages of $2.3779 \times 10^{-10}$ m²/s and $2.0930 \times 10^{-10}$ m²/s for the diffusivities of water and sucrose, respectively. These diffusivity values are similar to those reported by D'Aquino de los Santos et al. (2022) for papaya OD and by Wang et al. (2021) for mango. These values are also comparable to those reported by Ayala-Aponte et al. (2018), who reported the effective diffusivity for water and sodium chloride impregnated in green mango var. Filipino, with values on the order of $10^{-10}$ m²/s. Atares et al. (2009) reported that the effective water diffusivity was $1.53 \times 10^{-10}$ m²/s for apples and $1.05 \times 10^{-10}$ m²/s for sucrose. The diffusivities reported in this study were higher than those reported for Kent mangoes and apples in terms of effective water diffusivity. In the case of effective water diffusivity in papaya, it was approximately 5 times higher, and the effective sucrose diffusivity in papaya OD was approximately 8 times higher.

**Tabla 5**

*Values of $s_{PA}$, $\sigma_{PA}$, $s_{GS}$ and $\sigma_{GS}$ for water loss (WL) and solid gain (SG) in the Azuara model and the effective diffusivity of water and sucrose for osmotically dehydrated mango*

| Treatment | Model constants | | | | Diffusivities x $10^{-10}$ Di | |
|---|---|---|---|---|---|---|
| | $s_{PA}$ | $\sigma_{PA}$ | $s_{GS}$ | $\sigma_{GS}$ | ($m^2$/s) | ($m^2$/s) |
| 40°B,40°C,10psi | 2.4067 | 0.0142 | 1.2026 | 0.0104 | 0.7039 | 3.5204 |
| 40°B,50°C,5psi | 2.0423 | 0.0216 | 1.6407 | 0.0118 | 2.9933 | 2.1935 |
| 40°B,50°C,15psi | 2.0348 | 0.0269 | 3.4998 | 0.0174 | 1.4372 | 1.9652 |
| 40°B,60°C,10psi | 2.0471 | 0.0252 | 4.2004 | 0.0125 | 2.7377 | 1.8648 |
| 50°B,40°C,5psi | 3.1662 | 0.0210 | 2.1765 | 0.0049 | 1.8258 | 1.0406 |
| 50°B,40°C,15psi | 1.9050 | 0.0279 | 3.8507 | 0.0183 | 2.2366 | 3.1878 |
| 50°B,50°C,10psi | 2.5746 | 0.0241 | 1.2769 | 0.0136 | 2.2710 | 3.4828 |
| 50°B,60°C,5psi | 2.4811 | 0.0221 | 2.8447 | 0.0089 | 3.3496 | 1.0189 |
| 50°B,60°C,15psi | 1.7696 | 0.0321 | 4.2399 | 0.0175 | 2.1593 | 0.5452 |
| 60°B,40°C,10psi | 2.3842 | 0.0269 | 2.5762 | 0.0105 | 1.2480 | 2.3757 |
| 60°B,50°C,5Ipsi | 1.8610 | 0.0281 | 4.9296 | 0.0077 | 4.2516 | 0.5317 |
| 60°B,50°C,15Ipsi | 1.7509 | 0.0354 | 3.3952 | 0.022 | 3.9254 | 1.9081 |
| 60°B,60°C,10Ipsi | 1.6553 | 0.0347 | 3.2474 | 0.0159 | 1.7833 | 3.5737 |
| Average | | | | | 2.3779 | 2.0930 |

*Implications of the study for industry and future research*

This study lays the technological groundwork for the industrial processing of the Oro mango variety, with the aim of extending its shelf life and diversifying its commercial presentation. The feasibility of applying osmotic dehydration using a sucrose solution at 50°Brix and a temperature of 50°C without the use of vacuum pulses was evaluated. Under these conditions, a product with lower moisture content was obtained, and it received a favorable overall sensory rating from the evaluation panel.

This study explored the potential of osmotic drying as a preservation method for Oro mango varieties. However, further research is needed to determine the shelf life of the resulting products. Likewise, future research should focus on the development of dried mango slices by combining osmotic drying and hot-air drying, with the aim of optimizing product stability and increasing its added value on the market.

## CONCLUSION

This study demonstrated that the osmotic dehydration of slices of mango (*Mangifera indica* L.) var. Oro was affected by the concentration and temperature of the osmotic solution. Water loss from the mango can be maximized by using a 60 °Brix osmotic solution at 57°C, applying a vacuum pulse of 5 psi, while solid gain can be minimized by using a 47 °Brix solution at 43°C, applying a vacuum pulse of 8.4 psi. The optimization revealed that it is possible to use a solution at 53 °Brix, 51°C, and a vacuum pulse of 7.65 psi to maximize water loss and minimize sucrose gain. Sensory analysis revealed that the highest acceptability was obtained for the mango samples that were osmodehydrated at 50 °Brix at 60°C, with a vacuum pulse of 15 psi (7.38). Response surface methodology provides a suitable model for predicting water loss in mangoes during osmotic dehydration and, to a lesser extent, solute uptake; however, the Azuara model allowed for the calculation of the effective diffusivity of water and sucrose, both of which were on the order of 10–10 m2/s during the osmotic dehydration of mangoes.[1]

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# Secondary intestinal intussusception to a GIST tumor in a girl

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*— Abstract—*

GIST tumors are the most common mesenchymal tumors of the gastrointestinal tract in adults, but are very rare in children. We report the case of a 9-year-old female patient with abdominal pain and the ultrasound suggested intestinal intussusception. During the exploratory laparotomy, an intraluminal tumor was found, which subsequently confirmed the diagnosis of Gist tumor. She did not receive chemotherapy treatment. She has been under observation for more than 5 years without evidence of metastasis or recurrence. We carry out a brief discussion and analysis of the literature on GIST tumor in children.

**Keywords:**
*GIST tumor in children; causes of secondary intussusception; Digestive tract bleeding.*

Gastrointestinal stromal tumors (GISTs) are the most common mesenchymal tumors of the digestive tract; they originate in the interstitial cells of Cajal, which are responsible for peristaltic activity in the digestive tract, and are characterized by the expression of the tyrosine kinase receptor CD117 (KIT). Most GISTs harbor gain-of-function mutations in the v-KIT (KIT) or platelet-derived growth factor receptor alpha (PDGRFA) genes, resulting in the activation of kinases that promote neoplastic proliferation in 80% of cases.[1]

Currently, the term GIST refers to CD117-positive, spindle-shaped or epithelioid mesenchymal tumors that are primary to the gastrointestinal tract, mesentery, and retroperitoneum. This term was first used in 1983. Mazur and Clark used it to describe non-epithelial tumors of the gastrointestinal tract that lacked the ultrastructural features of smooth muscle and the immunohistochemical characteristics of Schwann cells.[2]

It is the most common sarcoma of the gastrointestinal tract (GIT). It accounts for 2% of tumors in this region but 80% of gastrointestinal sarcomas. Its incidence is estimated at 10 to 20 cases per million people per year. Its prevalence is higher due to the long clinical course of the disease (10–15 years).[2,3]

The peak incidence occurs between the 4$^{th}$ and 6$^{th}$ decades of life, with a similar distribution across genders. However, recent studies suggest a slightly higher incidence in males. It is rare in the pediatric population, with an annual incidence of 0.02 to 0.44 cases per million in individuals under 20 years of age. [3,4]

GISTs share immunophenotypic similarities with Cajal interstitial cells, which are located around the myenteric plexus and scattered throughout the muscularis propria. Characteristics such as the expression of KIT, CD34, the heavy chain of smooth muscle myosin, and nestin are common to both. Cajal interstitial cells act as pacemaker cells mediating between the nervous system and the smooth muscle system. They express CD117 in 95% of cases, just like GISTs, and exhibit a mixture of neural and myogenic features in their ultrastructure.[5]

In 1998, Kinblom suggested that GISTs originate from a stem cell that differentiates into a Cajal interstitial cell. The precursor cell hypothesis would explain why mesenchymal tumors with histology similar to GISTs, which are CD117-positive, can occur in the omentum and mesentery.[5]

Our aim is to present a rare case of GIST in a pediatric patient that presented with symptoms of intussusception, along with the results of treatment and a review of the literature.

## CLINICAL CASE

A 9-year-old female patient presenting with abdominal pain that began 20 days prior. She had previously received multiple treatments with antiparasitic and antidiarrheal medications without clinical improvement, leading her to seek care at our facility for persistent abdominal pain. Physical examination revealed generalized pallor; a holosystolic murmur in the precordial area secondary to “anemic heart”; tachycardia;

mild respiratory distress; a soft, depressible abdomen that was not tender on palpation; decreased peristalsis; and no signs of peritoneal irritation.

A complete blood count (CBC) was performed, revealing severe hypochromic microcytic anemia (4 gr/dl), a white blood cell count of 6,500/mm$^3$, and normal differential and platelet counts. An abdominal ultrasound was ordered and revealed intermittent colonic intussusception. She was evaluated by pediatric surgery, and an exploratory laparotomy was performed; a jejuno-ileal intussusception was observed secondary to a palpable mass in the intestinal lumen measuring approximately 2 cm in diameter. Resection of the segment and an entero-entero anastomosis were performed. Examination of the remainder of the small intestine and colon was normal.

The histopathological report indicated a gastrointestinal stromal tumor (GIST) with polypoid growth into the intestinal lumen (Figure 1), describing epithelioid and spindle cells with more than 5 mitoses per field. Immunohistochemistry confirmed positivity for: CD117, DOG1, and CD34.

The patient remains asymptomatic and has been tumor-free for 5 years following surgical resection.

## DISCUSSION

The etiology of intussusception is usually inflammation of Peyer's patches in infants. In a patient over 2 years of age presenting with intestinal intussusception, one must always look for an organic or secondary cause. In this pediatric case, which appears to be the first reported in Mexican literature, the jejuno-ileal intussusception was caused by a gastrointestinal stromal tumor.

Kinblom and colleagues conducted a population-based study, collecting epidemiological and prognostic data on GISTs. In a Swedish population of 1.3–1.6 million people, with four referral hospitals, they investigated c-KIT-positive mesenchymal tumors between 1983 and 2000. They studied 650 cases, of which 398 met the diagnostic criteria for GIST. Seventy-two percent of the GIST cases had been diagnosed with another condition. 28% were diagnosed with GIST, 34% with leiomyomas, 18% with leiomyosarcomas, 13% with leiomyoblastomas, and 7% with other diagnoses. Regarding clinical presentation, 69% were symptomatic, with most symptoms being nonspecific: vague pain, anorexia, anemia, weight loss, and nausea. Less common were gastrointestinal bleeding (due to mucosal ulceration) or intraperitoneal bleeding (due to tumor rupture).[6]

In our patient, the tumor was found at the jejuno-ileal junction, which is very rare, as Kindblom reports that they can be located in the upper gastrointestinal tract (GIT), the mesentery, or the retroperitoneum. Between 50% and 60% of cases originate in the stomach, 20% to 30% in the small intestine, approximately 10% in the colon, and the remaining 15% in other sites: the rectum, esophagus, mesentery, and retroperitoneum. The esophagus accounts for 5% of cases.[3,4]

The macroscopic appearance depends on the size, which ranges from 1 to 32 cm, although most are larger than 2 cm. In our patient, the intraluminal tumor measured 1.5 cm. They appear as serous, intramural, or submucosal nodules. Large tumors typically exhibit exophytic growth, toward the lumen, with or without mucosal ulceration (20–30% of cases). They may also protrude toward the serosa with a large extraparietal component, which masks their gastrointestinal origin on imaging studies. Histologically, three architectural patterns are distinguished in GIST tumors: spindle cell (70%), epithelioid (20%), and mixed (10%). In our patient, a mixed type was found: spindle or spindle-shaped cells and epithelioid cells.[7]

The presentation of GIST varies in terms of symptoms and signs, depending on the tumor's size and location. In our patient, chronic abdominal pain was the predominant symptom. She has no history of hematemesis or melena; however, occult blood in the stool is possible due to chronic, unnoticed gastrointestinal bleeding.[7]

Ultrasound is often the initial diagnostic technique used in many patients with GIST tumors. These tumors are typically large and hypoechoic; in our patient, ultrasound did not detect the tumor prior to surgery, leading to a diagnosis suggestive of intussusception. Other recommended imaging studies include contrast-enhanced abdominal CT, considered the most sensitive technique, in which GIST tumors are described as hypervascular masses with a heterogeneous appearance due to hemorrhagic necrosis or cystic degeneration, and magnetic resonance imaging (MRI) if a rectal tumor is suspected.[8]

GIST tumors have immunohistochemical characteristics that are useful for confirming the suspected diagnosis. Approximately 95% are positive for KIT (CD117), 98% for DOG-1, 80% for PDGFRA, 70% to 80% for CD34, and 30% to 40% for smooth muscle actin and others [2,9,10] Thirty percent of GISTs are malignant, and currently there are at least four risk stratification systems (Fletcher, Miettinen, the Armed Forces Institute of Pathology [AFIP], and the risk criteria of the National Comprehensive Cancer Network [NCCN]), which generally consider the following variables: tumor size, mitotic rate per high-power field, and tumor site. In the case we present, the tumor size was less than 5 cm, the mitotic rate was greater than 5 per field, and the location was in the jejunoileal region; thus, based on AFIP criteria, it would be classified as moderate risk.[11] In children, the most common location is the stomach, and the disease typically presents with multiple tumor nodules (multifocal disease). In Mexico, Morales et al. reported two cases located at the esophagogastric junction and within the gastric cavity, presenting with chronic anemia; treatment consisted of surgical resection in one case and neoadjuvant therapy with imatinib in the second case.[12]

The prognosis shows some association with anatomical location, with a tendency for those located in the small intestine to be more malignant than those located in the stomach.[11] In a study of 1,700 gastric GISTs, Miettinen[10] observed that 83% were benign. In the duodenum, however, half are typically malignant. In the esophagus,

they are rare. Leiomyomas are the most common. However, more than half of GISTs are malignant. Other locations have been described, such as in the lymph nodes.[13,14]

The primary treatment for GISTs has been surgical resection, especially for localized tumors; whereas malignant GISTs are treated with various regimens of chemotherapy and/or radiation therapy, with a reported 5-year overall survival rate of approximately 12%, particularly in unresectable or metastatic tumors that relapsed or progressed and were resistant to cytotoxic chemotherapy and/or radiation therapy.[15] In recent decades, with a better understanding of the molecular mechanisms that give rise to these neoplasms, therapies have emerged that target these mutations at specific sites, thereby altering tumor proliferation and angiogenesis. Tyrosine kinase inhibitors block KIT and PDGFRA receptors (present in 90% and 80% of GISTs, respectively) and represent the current standard of care for reducing relapses and for the high-risk group; Imatinib is one of the first drugs with this mechanism of action, reducing the risk of disease progression or death by 54%.[15,16]

Given the rarity of these tumors in the pediatric stage, there are no specific treatment recommendations; the reported approaches have been extrapolated from the management of adult patients. Arimatias et al., in their systematic review that included 184 patients—68% of whom were women, with a mean age of 14 years—found that the tumor was located in the stomach in 90% of cases and in the intestine in 7%. Initial management consisted of partial to total gastrectomy; 46% of cases had metastatic disease at diagnosis and received standard chemotherapy in 2%, first-generation tyrosine kinase inhibitors in 34%, and second-generation tyrosine kinase inhibitors in 13%, achieving complete remission in 52% and an overall survival of 24% at 6 years.[17]

In our case, based on the histological findings, the tumor was classified as moderate-risk; the treatment plan involved complete resection without any adjuvant therapy, and at 5 years of follow-up, the patient remains free of tumor activity.

## CONCLUSIONS

It should be noted that intussusception is idiopathic in 90% of cases and occurs in infants. When intussusception occurs in children older than 2 years, there is always an organic or secondary cause, as in the case described here.

This is the first reported case of a GIST in a 9-year-old child, treated with surgery alone, who remains free of tumor activity 5 years after diagnosis.

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## Annex

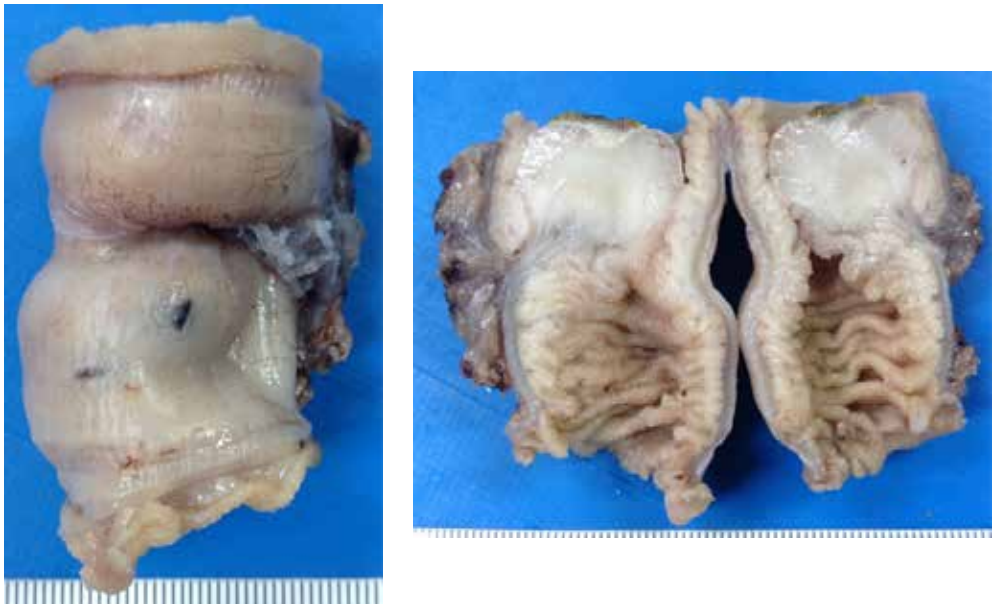

***Figure 1.*** Macroscopic Description: A 6 × 3 cm Segment of the Jejunum with a polypoid mass showing traction on the intestinal wall

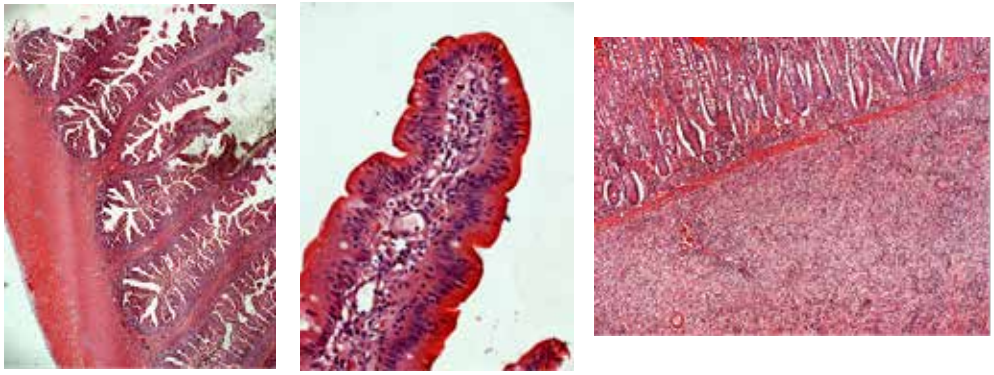

***Figure 2.*** Microscopic Description. Proliferation of cells forming a polypoid mass originating from the lamina propria and muscle layer, without involvement of the superficial mucosa, is observed

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# Relationship between academic stress, eating disorders and mental health in University Students

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*— Abstract—*

The text presents an analysis of academic stress, eating disorders, and mental health among undergraduate students in the Pedagogy and Information and Communication Technologies Applied to Education program at the Faculty of Humanities, Autonomous University of Chiapas. It is understood that academic stress is one of the primary sources of discomfort for university students, stemming from the constant pressure to meet academic demands. This situation affects emotional management, leading to problems such as anxiety, low self-esteem, and difficulties in relationships. In some cases, excessive stress can cause mental health imbalances, manifesting in disorders such as generalized anxiety and eating disorders. These situations can trigger self-harming behaviors, aggression, and even school dropout, which prompted the investigation with the aforementioned students.

The average age of the participants is 23 years, with a notable gender disparity (67.7% men and 32.3% women). Regarding academic stress, moderate levels are more common in the early semesters, while high and very high levels dominate in advanced semesters, particularly in the seventh and eighth semesters.

In terms of eating disorders, moderate and low levels are the most frequent, but very high levels increase in more advanced semesters. Regarding mental health, a balanced distribution is reported across different levels, although women tend to show lower mental health indicators.

No significant correlation was found between emotional levels and stress, nor between academic stress and digestive symptoms. However, a moderate negative correlation was identified, suggesting that better emotional well-being is linked to a lower prevalence of digestive symptoms.

**Keywords:**
*Academic stress; mental health; emotions; eating disorders.*

Stress is regarded as a primary source of emotions across all human activities and has been a key focus for researchers in various fields of knowledge. In recent years, the interest of numerous researchers has centered on specific populations, such as university students.

Various theories, including the transactional theory, posit that stress is a cognitive event in which the individual evaluates it as a source of opportunity or as a threat. Meanwhile, Lazarus's theory (1991), as cited by Gil (2016), describes it as an evaluative process linked to decision-making itself, which is tied to emotions. However, Calixto-González (2019) notes that for McEwen (2000), it represents a real or imagined threat to physical or psychological integrity, prompting a behavioral or physiological response.

Meanwhile, academic stress, according to the World Health Organization (WHO, 2021), involves the physiological, emotional, cognitive, and behavioral activation in response to academic stimuli and events. Mental health, in turn, is an essential component of overall health and must be promoted and protected accordingly. Numerous studies have shown that university students face high levels of academic stress, which can have a negative impact.

The purpose of this work was to reflect on the relationship between academic stress, eating disorders, and emotions in the mental health of students from the Pedagogy and TICAE degree programs at UNACH. Academic stress is an inherent reality of university life and has become a widely studied phenomenon due to its impact on students' mental health. The Pedagogy degree at the Universidad Autónoma de Chiapas (UNACH) is no exception, as students face challenges that extend beyond academic demands. Following the return to in-person classes after the pandemic, an increase has been observed in disruptive behaviors, emotional crises, and demotivation, raising questions about how academic stress is influencing students' emotional stability and psychological well-being. Despite advances in understanding this topic, there remains a need to better comprehend the relationship between academic stress and mental health in this specific context, particularly among students in the Pedagogy and Information and Communication Technologies (TICAE) degree programs.

## DEVELOPMENT

This section addresses mental health as a crucial element for the overall well-being of university students, where academic, personal, and social challenges converge to influence their performance and quality of life. Drawing on an analysis of various academic sources, it highlights definitions of mental health provided by international organizations such as the World Health Organization (WHO) and the Pan American Health Organization (PAOH), along with legal and research perspectives that underscore the importance of protecting and promoting emotional and psychological stability.

This section outlines the main threats faced by university students, such as academic stress, workload-related demands, exams, and eating disorders – including anorexia, bulimia, and binge-eating disorder. These conditions not only affect physical health but also produce significant impacts on mental health, exacerbating issues like anxiety and depression.

Mental health interferes with daily activities; therefore, it is essential to safeguard it in order to maintain a good quality of life, particularly in the university setting, as it fosters academic performance and the fulfillment of academic responsibilities. Various authors analyze mental health from psychological and psychiatric perspectives, including the World Health Organization (WHO, 2022), which defines mental health as "a state of mental well-being that enables people to cope with the stress of life, develop their abilities, learn and work adequately, and contribute to their community" (para. 1). This allows individuals to develop and strengthen their capacities and skills, as well as apply them in professional and social contexts, while also enabling sound decision-making, meaningful relationships with others, and the anility to confront the situations or challenges that may rise.

From Miranda's (2018) perspective, mental health is viewed as "a state or condition of the of the individual, a field -conceptual and practical- within public health, a series of psychiatric pathologies and psychosocial problems" (p.86). Therefore, mental health is related to the well-being of the person and the absence of psychosocial problems, it is important to mention that mental health is closely linked to physical health, for instance, a person experiencing a depressive state may present symptoms such as lack of appetite, increase or absence of sleep appear, as noted by the Pan American Health Organization (PAHO, 2020) when saying as a motto "There is no health without mental health" (paragraph 1). Nevertheless, emotions play a significant role in mental health; therefore, it is necessary to have good management of emotions to maintain good mental and emotional stability.

The subject of health has been reflected in legislation, as noted by the Ministry of Health and Social Protection (2013) of Colombia, which, in accordance with one of its laws, defines mental health as:

> a dynamic state expressed in everyday life through behavior and interaction, in such a way that enables individuals and groups to deploy their emotional, cognitive, and mental resources to navigate daily life, to work, to establish meaningful relationships, and to contribute to the community (Law 1616 of 2013).

This definition takes into account mental health, personal relationships, and the environment, as well as thoughts and beliefs, while also recognizing the role of society, which determines how a person will shape an individual's mental health. It is further worth noting that research has been conducted on mental health, for example, Cuamba and Zazueta (2020), whose study, entitled Mental Health, Coping Skills, and Academic Performance in University Students, found, through the

Level 1 Cross-Cutting Symptom Measure of the DSM-5 and the Coping Strategies Inventory (CSI), that half of the students presented mental health problems and difficulties in the execution of coping skills.

### *Main threats*

There are threats that jeopardize good mental health, such as "insecurity, hopelessness, rapid social change, risks of violence, problems affecting physical health, personal factors and experiences, social interaction, cultural values, and family, school, and work experiences, which are some of the elements that affect it" (Fundación UNAM, 2019, para. 2). These can negatively impact mental health, for example, poverty, which, due to a lack of financial resources, lowers a person's self-esteem and motivation; or, if a person constantly experiences situations of violence, they tend to present emotions such as fear, sadness, despair, anguish, and anger. Furthermore, when individuals lack the means to confront or resolve these situations, not only is their mental health damaged, but mental disorders may also emerge, the latter being defined as "a clinically significant disturbance in an individual's cognition, emotional regulation or behavior" (WHO, 2022, para. 1).

There are various disorders that jeopardize mental health; however, the most common are depression and anxiety. In the case of the former, "the person experiences a depressed mood (sadness, irritability, feeling of emptiness) or a loss of pleasure or interest in activities" (WHO, 2022, para. 4), and in the most severe cases, suicide may occur. According to WHO (2022), "In 2019, 280 million people suffered from depression, including 23 million children and adolescents" (para. 4). This is particularly relevant given that children and adolescents (the majority of whom are students) are among those affected by this disorder, as they face concerns related to fulfilling academic, daily, and even work-related responsibilities. On the other hand, anxiety refers to "fear and excessive worry and related behavioral disturbances. The symptoms are severe enough to cause distress" (WHO, 2022, p.3), and WHO (2022) states that "In 2019, 301 million people suffered from anxiety disorder, including 58 million children and adolescents" (para. 3). It should also be noted that Cuenca, Robladillo, Meneses, and Suyo (2020), in their study on mental health in Latin America university adolescents, a systematic review, found that women ten to present mental disorders and stress-related conditions first.

### *Challenges*

Mental health is a human right; therefore, its primary challenge lies in its own protection, which must be supported through plans and programs aimed at eradicating the problem. Equally important is the need for specialized areas within school, particularly universities, dedicated to addressing mental health issues, staffed with psychologists or psychopedagogical counseling services, as is the case at UNACH, which provide support for psychoemotional difficulties and for students at risk

of dropout or program abandonment. Ultimately, the foremost challenges facing mental health are raising awareness within society and educational institutions.

*Academic Stress*

Stress is a factor experienced by the majority of the population in daily situations, with the distinction that it occurs under pressure; however, in the academic environment it manifests more frequently, particularly among university students. Academic stress "emerges from an interaction between environmental stressors and student reactions, and is associated with frustration and academic failure" (Tirado et al., 2023, p.1). Stress represents one of the main causes of harm to university students' mental health, as evidenced by Carreón et al.'s (2023) research on academic stress and mental health issues in nursing students during the COVID-19 pandemic. Their findings revealed that university students at moderate stress levels presented mental health problems along with severe manifestations of anxiety, depression, and insomnia, establishing the need to create educational strategies and training programs to reduce these disorders that compromise nursing students' mental health.

*Causes*

Multiple causes can trigger stress that encompasses not only academic dimensions but also personal and family aspects. It should be noted that these causes depend on age, gender, social environment, behavior, academic major, and coping strategies. "When discussing academic stress, the causative factors can be numerous, if simply entering university is already stressful, continued enrollment and daily obligations can induce stress" (Sarubbi de Rearte & Castaldo, 2013, p.292). Regardless of the specific causes of stress, they will ultimately harm both mental and physical health. Before discussing the causes, it is important to note that academic stress can affect students in various ways, whether personally or within the family. Nevertheless, "It is also viewed as the pressure that helps one face and overcome unpleasant or painful situations. A certain amount of stress is not bad, since it allows one to face challenges and stay motivated." (Sarubbi de Rearte & Castaldo, 2013, p.293). Among the identified causes of academic stress are the following:

**Workload**

This cause is one of the main triggers of academic stress. It refers to the excessive number of activities performed by a single person, but in the educational context, students must dedicate a certain amount of time to studying and completing their assignments. Therefore, they must conduct a literature review or information search to be able to understand the course assignment. As García and García (2017) express, "The expected workload, by modules, subjects or subjects, is used in the design of the study plans" (p.84). It should be remembered that academic assignments must

provide learning, promote research, and foster study habits. It is not only about offering students skills but also about measuring the quantity of assignments so that they can enjoy their studies and safeguard their mental health.

**Exams**

An exam is a written or oral test administered to students to assess what they have learned during the course; as a result, students must study for days or weeks to take the exam and try to earn good grades, which can lead to high levels of stress and negatively impact their mental health. From another perspective, "Assessment can be understood in various ways, depending on the needs, purposes, or objectives of the educational institution; such as: monitoring and measurement, assessing the validity of the objective, and accountability, to name a few purposes." (Mora, 2004, p.2).

It is recommended to use other types of assessments, such as individual or group final projects, portfolios, essays, or simply evaluating students based on their work throughout the course, because "school exams are typically viewed and experienced by students as a threat, as a distressing and unpleasant experience." (Pérez, 2006, p. 7) Therefore, eliminating exams would reduce stress among college students.

There are also other causes of academic stress, as stated in the research by Londoño et al. (2024), which found that in addition to an overload of schoolwork and taking exams, a teacher's lack of methodological skills is also a cause of academic stress; furthermore, "when school-related stress is excessive, psychological problems may develop, particularly certain mental health disorders" (Maturana & Vargas, 2015, p. 37). Consequently, mental health is affected by factors related to academic stress; therefore, it is important to take measures to prevent the onset of mental disorders in students by reducing activities that may be considered stressful.

**Academic requirements**

Throughout their university journey, students face situations that require them to complete assignments or projects, give presentations, conduct research, and take exams—not to mention their class schedules. All of these are academic demands that, as Huaquín and Loaíza (2004) note, "act as curricular stressors or stimuli that elicit responses specifically known as student stress." (para. 7) These demands will always come from the teacher, because they are responsible for ensuring that their students achieve the expected learning outcomes; therefore, they must require students to complete the activities they assign, attend class, and pay attention. Students even demand that their peers complete school projects or presentations, as noted by Flores (n.d.):

> Academic demand reflects the rigor the intensity with which academic activities are carried out, and it is the result from an unique combination of various factors,

> including faculty (teaching skills, preparation, enthusiasm), students (vocation, motivation, conditions), institutional policies, the learning environment, program design, and learning assessment. (p. 2)

Academic demands cause stress among students, leading to widespread anxiety, which can affect their well-being and, consequently, their mental health.

**Eating disorders**

Before examining eating disorders, it is important to note that eating behavior is defined as: "normal behavior related to eating habits, the selection of foods consumed, food preparation, and the quantities consumed." (Osorio, Weisstaub, & Castillo, 2002, para. 1). When discussing eating disorders, we refer to a disruption in eating behavior that completely affects physical and mental health; furthermore, they can be life-threatening if not treated in time, and they are also "characterized by abnormalities in eating habits that may involve either insufficient or excessive food intake, affecting the individual's physical and emotional health." (Tabárez, 2016, p.16); it is adolescents who most commonly suffer from these types of disorders, often influenced by social media or school experiences where they receive negative comments about their bodies; which leads them to begin devising ways to achieve the perfect body.

> A large proportion of adolescent girls suffering from these disorders do not seek treatment directly because, in general, their awareness of the illness and motivation to change are scarce, even though their physical and psychological health is severely threatened by the disease (López & Treasure, 2011, p. 86).

Eating disorders are considered mental health illnesses that are often identified by family members, friends, and teachers. These are illnesses that become chronic over time, manifesting as changes in eating habits and excessive exercise; they even affect social relationships and daily activities. There are three types of disorder that affect a person in different ways. They require a diagnosis, medical and psychological treatment, and even help of a nutritionist to provide the individual with a diet that helps them recover a healthy lifestyle.

Anorexia

Known as anorexia nervosa, it affects eating habits; the person reduces the frequency and portions they eat in order to lose weight, in other words, they suppress their appetite despite feeling hungry; these individuals refuse to eat even a single bite. It has also been shown that people with anorexia experience emotional problems such as depression stemming from a desire to have the ideal body or to

be accepted by a society that promotes ideologies about the perfect body. Nuñez et al. (1995) describe anorexia nervosa as:

> It can be considered the final stage of a continuous process that begins with conscious weight loss for aesthetic reasons, progresses through a phase of neurotic preoccupation with weight and food intake, and culminates in a condition characterized by uncontrollable eating behavior and a clear distortion in the perception of one's body image. (p. 9)

Most people who experience anorexia are adolescent females who seek to look good through weight loss. García and Murray (2023) reveal that: They show a peak incidence between 14-19 years of age, with a predominance among females; however, an increase in frequency is observed at younger ages (school age). (p. 520) From an early age, girls begin to fixate on the idea of being perfect, harming themselves physically and mentally; therefore, living in these types of situations is often stressful for them.

Bulimia and Binge Eating Disorder

This disorder is similar to anorexia, with the difference that the person consumes large quantities of food and subsequently induces vomiting in order to avoid weight gain. It is difficult to detect because most people who suffer from it keep it secret due to shame or fear of what others will say about them. In the words of Sierra (2005):

> the essential features of bulimia nervosa include binge eating and inappropriate compensatory behaviors (self-induced vomiting, misuse of laxatives, diuretics, or other medications, fasting, or excessive exercise) to prevent weight gain (employed on average twice weekly for a minimum of three months) (p.80).

Bulimia can trigger mental disorders including depression and anxiety stemming from the compulsive need to induce vomiting to control weight. This disorder poses significant danger as it affects major bodily systems, particularly the stomach, which without timely intervention can lead to death. Moreover, the Secretariat of Health (2017) reported that "approximately 20,000 cases of anorexia and bulimia are registered annually in Mexico, with individuals aged 15 to 19 being most affected" (para. 1). Educational institutions from elementary through tertiary levels must implement awareness programs addressing these disorders that can severely compromise the mental stability of adolescents and young adults who become preoccupied with weight management through harmful practices at the expense of their academic and personal pursuits.

Unlike the aforementioned disorders, binge eating disorder is characterized by the consumption of excessive amounts of food within brief timeframes. Sufferers do

not monitor caloric intake but subsequently experience profound guilt following binge episodes. Individuals with this disorder typically present with overweight of obesity. "Binge eating disorders is formally recognized in the DSM-5 as a feeding and eating disorder and is considered the most prevalent among obese populations, with its incidence rapidly increasing relative to other disorders in the general population" (Cuadro & Baile, 2015, p.97).

People with this disorder exhibit no control over their eating habits, failing to experience satiety after food consumption. The Secretariat of Health (2016) reports that for every two men presenting with this disorder, an estimated three women are also affected, predominantly over 30 years of age, with prevalence reaching 25 to 30 percent among the obese or overweight population (para. 3). Medical and psychological intervention is required to mitigate binge eating symptoms.

Mental health among university students is crucial for optimal academic performance; however, throughout their academic journey they face circumstances that progressively compromise their mental well-being, particularly academic stress resulting from pressure to meet academic, personal, and often professional obligations. Furthermore, female students experience eating disorders that compound mental health deterioration. Consequently, educational institutions must implement awareness programs addressing mental health care in relation to the challenges that may affect it, as well as eating disorders, to ensure students sustain mental stability throughout their degree programs.

## METHODOLOGY

This research is descriptive-interpretative in nature, which involved, in the first stage, the search and selection of background information and theoretical foundations on mental health and academic stress; in a second stage, fieldwork consisting of the administration of a survey; and in a third stage, the description and analysis of the collected information. The instrument employed was a questionnaire, administered as a survey, consisting of 67 items divided into four dimensions: emotions, addictions, eating disorders, and stress. The survey was administered through Google Forms, and data analysis was carried out using SPSS Statistics version 21.

The research subjects were 235 students enrolled in the Bachelor's degree program in Pedagogy and Information and Communication Technologies Applied to Education (TICAE) at the Universidad Autónoma de Chiapas (UNACH), located in Tuxtla Gutiérrez, Chiapas, Mexico. Regarding the diversity of ages, a significant range was observed, from a minimum of 17 years to a maximum of 56 years. This broad spectrum reflects the heterogeneity present in the student population of the faculty. The average age of the students is 23.3 years.

The results of the item reliability for the various categories of analysis related to stress and mental health among Pedagogy and TICAE students are presented as follows:

The analysis category "Emotions" shows high reliability with a Cronbach's Alpha coefficient of 0.94. This result indicates substantial internal consistency among the items related to emotions in the measurement.

The "Eating Disorders" analysis category exhibits exceptionally high reliability, with a Cronbach's alpha coefficient of 0.96. This suggests strong and reliable internal consistency in the measurement of items associated with eating disorders.

The "Stress" and "Mental Health" analysis categories exhibit high reliability, with a Cronbach's alpha coefficient of 0.94. This indicates robust internal consistency among the stress-related items in the evaluation.

The results suggest that the items related to emotions, eating disorders, and stress in the evaluation demonstrate robust and reliable internal consistency. The exceptionally high reliability in the "Eating Disorders" category suggests that the items associated with this dimension are particularly consistent with one another in their measurement. These findings support the internal validity of the measurement tool used to evaluate stress and mental health in Pedagogy and TICAE students.

## RESULTS

The study examined the impact of academic stress, emotions, eating disorders, and mental health on college students, taking into account differences in age, gender, and semester. With a sample of 235 participants—mostly men (67.7%) with an average age of 23.3 years—the analysis provided a detailed overview of the emotional and health dynamics faced by young people in academic settings.

This analysis provides a comprehensive overview of how perceptions of academic stress vary across different age groups, which is crucial for understanding the dynamics of academic stress among students.

First, regarding academic stress by gender, the overall distribution of the sample shows a higher proportion of male participants, accounting for 67.7%, compared to 32.3% of female participants.

Among male participants, 20.8% experience low levels of stress, while 27.7% report moderate levels, 23.9% report high levels, and another 27.7% experience very high levels of stress. In contrast, among female participants, 38.2% report low levels of stress, 19.7% moderate levels, 25.0% high levels, and 17.1% experience very high levels.

These results indicate that in general, women tend to experience lower levels of stress compared to men. A significantly higher proportion of women fall into the "Low Stress" category, while a smaller proportion fall into the "Moderate" and "Very High Stress" categories compared to men.

These gender differences in the perception of stress are notable and suggest that the impact of stress may vary between men and women in the study population. These findings underscore the importance of considering gender when developing intervention strategies and programs that address stress and promote psychological

well-being, taking into account the specific needs of each group. These results also provide a valuable foundation for future research exploring the underlying causes of these differences and their relevance in specific contexts.

An analysis of academic stress by semester reveals significant variations throughout the college experience, with notable differences in the prevalence of stress levels. In the first semester, moderate and low stress stand out as the predominant categories, each affecting 34% of students, while high and very high levels have a lower incidence (18% and 14%, respectively). This indicates an initial phase in which adaptation is challenging but manageable.

However, in the second semester, a notable shift occurs: very high stress becomes the most prevalent category at 33.3%, followed by moderate stress (27.3%). This increase in stress can be attributed to students adapting to academic demands and adjusting to the university environment.

In the third semester, moderate stress levels were again prevalent (28.6%), although very high stress levels remained significant (31%), indicating that the demands remain constant.

The fourth semester is notable for the high prevalence of high stress levels (37.5%), while low and moderate stress levels each account for 25% of the total, suggesting a significant increase in academic pressure.

The fifth semester shows a more even distribution across all categories, with moderate and very high stress levels reaching 22.2% and 31.1%, respectively, indicating a fluctuating balance between academic workload and adaptation.

In the sixth semester, high stress levels reach a significant peak (80%), making it the most critical semester in terms of academic pressure.

In the seventh semester, moderate (30.4%) and high (34.8%) stress levels are predominant, while very high stress remains significant (26.1%), indicating an advanced but still intense phase in terms of academic workload.

Finally, in the eighth semester, moderate (31%) and high (34.5%) stress levels remain the predominant categories, showing a notable balance compared to other semesters.

In this category, moderate stress is the most common condition across all semesters, accounting for 26.4% of the total. However, peaks of high and very high stress in specific semesters, such as the second and sixth, highlight the need for targeted interventions during these critical periods to mitigate the impact of stress on students' mental health and academic performance.

### *Emotions*

Emotions are complex psychophysiological responses to stimuli that have both a subjective component and an objective expression. They are subjective experiences that arise in response to internal or external stimuli and are typically accompanied by physiological changes, facial expressions, behavioral responses, and specific cognitive patterns.

Emotions can also be complex and varied, combining aspects of basic emotions. For instance, envy may be a combination of sadness and displeasure, and love may involve joy, affection, and other emotional components.

The results presented offer a comprehensive overview of college students' emotional well-being based on various factors such as age, gender, and academic semester, using the Emotional Scale for University Students. Through this assessment, significant patterns and notable differences in participants' emotional responses are identified.

*Emotions by Age Group*

Students in the 17- to 21-year-old group, accounting for 55.7% of the sample, represent the majority in this study. This group shows an even distribution across the different emotional scales, with the "Very High" category standing out at 59%. This data suggests that younger students experience high levels of intense emotions, such as stress and frustration, which could be related to the transition to college life and academic pressure.

In contrast, the 22- to 26-year-old group shows a slight tendency toward the "High" scale, at 34.4%, indicating relative stability, though still with a considerable level of stress. As students get older, the number of participants decreases progressively. In the 27- to 31-year-old group, the "Moderate" scale predominates at 8.3%, reflecting a more balanced management of emotions, likely due to acquired maturity.

Older age groups, such as those aged 32 to 36 and older, tend to report lower or moderate emotional levels, with "Low" and "Moderate" being the most common categories. This could suggest that older students have better strategies for coping with academic demands or face different emotional challenges.

*Emotions by gender*

Analysis by gender reveals notable differences. Among men, the "Moderate" category is the most common, at 34%, followed by "High" at 27%. This indicates that men tend to experience less extreme and more stable emotions.

On the other hand, among women, the "Very High" category predominates at 27.6%, followed by "High" at 23.7%. This data suggests that women tend to experience more intense emotions, which could be related to social, academic, or personal factors that expose them to higher levels of stress and anxiety.

Overall, the "Moderate" scale is the most common among both genders, accounting for 30.6%, although women's tendency toward higher emotional levels highlights a significant disparity that warrants attention.

*Emotions by Academic Semester*

The distribution of emotions varies considerably across academic semesters. In the first semester, the "Moderate" scale is the most common, with 34% of responses, suggesting an initial adjustment period with relatively manageable emotional levels. In the second semester, the "High" scale increases significantly to 30.3%, indicating an increase in academic pressure.

In the fifth semester, the "High" category remains the most common at 33.3%, reflecting the accumulated workload and increased academic responsibilities. In the sixth semester, although the proportion is lower, the majority fall into the "Moderate" category (60%), which may indicate a slight stabilization before the final semesters.

The seventh and eighth semesters show a significant increase in the "Very High" category, at 39.1% and 20.7% respectively, indicating that the final stretch of the program involves higher levels of stress and pressure, possibly due to the completion of the degree, thesis defense, and the approaching graduation.

The results reflect significant emotional variability across different age groups, genders, and semesters, without a clear predictable trend. This underscores the importance of monitoring and supporting emotional well-being throughout one's academic life, as emotions do not follow a uniform pattern but fluctuate depending on various contextual and personal factors.

*Eating Disorders*

Eating disorders are conditions that affect a person's relationship with food and their body; among the most significant are anorexia nervosa, bulimia, and binge-eating disorder.

*Distribution by Age Group*

Among young people aged 17 to 21, moderate (26.0%) and high (29.8%) levels of eating disorders stand out, while low and very high levels have a lower prevalence. In the 22- to 26-year-old age group, the moderate level predominates (32.8%), followed by the low level (31.3%). Starting at age 27, a higher prevalence of the low level is observed, peaking in the 27–31 age group (57.1%) and the 42–46 age group (57.1%). In older adults, the very high level becomes significant, especially in the 47–51 age group (50.0%) and the single case in the 52–56 age group.

*Relationship to gender*

Among men, the high (25.2%) and moderate (24.5%) levels are the most common, with a more balanced distribution across all categories. Among women, moderate (30.3%) and low (31.6%) levels dominate, while the very high level is less prevalent (11.8%). Overall, the moderate level is the most common among both genders (28.1%).

*Relationship with Academic Semesters*

In the early semesters, moderate and mild eating disorders are more prevalent. However, toward the later semesters (seventh and eighth), the very high level becomes more prominent, reaching 39.1% in the seventh semester. This progression suggests a shift in patterns as academic training progresses.

Moderate eating disorders are the most common across all analyzed variables, accounting for 28.1% of the total, while low and high levels also have a significant presence. There is notable variability across age groups, gender, and semesters, reflecting differences in the factors associated with these categories.

*Mental Health*

Mental health encompasses a broad spectrum that includes managing emotions, preventing and treating mental disorders, and promoting healthy relationships and a sense of overall well-being. By recognizing the interconnectedness of emotions, eating disorders, and mental health as a whole, we can work toward a holistic approach that promotes a fulfilling and balanced life.

*Relationship with age groups*

Among young people aged 17 to 26, the "High" mental health category is the most common, with percentages close to 28%, accompanied by a balanced distribution across the other categories. Among adults aged 27 to 41, Low and Moderate mental health predominate, especially in the 27- to 31-year-old group (57.1% in Low) and the 37- to 41-year-old group (44.4% in Moderate). In older age groups (42 and older), the Low, Moderate, and Very High categories are similarly represented, except in the 52–56 age group, where only the High category is observed.

*Relationship to gender*

Among men, the "High" mental health category leads with 27.4%, while among women, the "Low" category predominates (30.3%). The "Moderate" and "Very High" categories show similar distributions across both genders, with a slight preference for the "Very High" category among men (26.8%) compared to women (18.4%).

*Relationship to the Academic Semester*

In the first semesters, "Moderate" mental health is predominant (32.7% in the first semester), but the "High" category becomes more prevalent in the second semester (28.1%). Toward the final semesters, the Very High and Low categories gain greater

prominence, reaching 47.8% and 30.4%, respectively, in the seventh semester. In the eighth semester, the Moderate (34.5%) and High (27.6%) categories lead.

Mental health is distributed relatively evenly across the categories of Low, Moderate, High, and Very High, although it varies by age group, gender, and academic semester. The Moderate and High levels are the most common overall, while the Very High level becomes more prevalent as students progress to later stages of both age and academic career.

### *Stress and Mental Health*

In the university setting, the link between stress and mental health is particularly evident. College students often face academic, social, and personal challenges that can lead to high levels of stress. The pressure to meet academic expectations, deadlines, competition among peers, and adjusting to a new and demanding environment can all contribute significantly to stress.

This constant pressure can take a toll on college students' mental health. The link between stress and mental health is reflected in an increased risk of disorders such as anxiety and depression, as well as in the exacerbation of pre-existing issues. Furthermore, academic stress can affect sleep quality, concentration, and decision-making, negatively impacting academic performance and overall quality of life.

## CORRELATION BETWEEN STRESS, EMOTIONS AND MENTAL HEALTH

The results of the correlation analysis between the variables "Emotions Scale," "Stress Scale," and "Digestive Disorders Scale" in a sample of 235 individuals, using Spearman's correlation coefficient.

The correlation between the "Emotions Scale" and the "Stress Scale" revealed a low correlation coefficient (0.003), with no statistical significance ($p = 0.962$). In other words, no appreciable linear relationship was found between these two variables in the analyzed sample.

In the sixth semester, the Moderate mental health category is the most prevalent (40.0%), followed by the Low (20.0%), High (20.0%), and Very High (20.0%) categories.

In the seventh semester, the "Very High" mental health category is the most common (47.8%), followed by the "Low" (30.4%), "Moderate" (4.3%), and "High" (17.4%) categories.

In the eighth semester, the Moderate (34.5%) and High (27.6%) mental health categories are the most prevalent, followed by the Low (13.8%) and Very High (24.1%) categories.

Overall, the distribution of the mental health scale shows variability across the different semesters. The Moderate mental health category is the most common, accounting for 24.0% of all students. The overall distribution of mental health across the four categories is relatively even.

### *Stress and Mental Health*

In the university environment, the correlation between stress and mental health is prominently manifested. University students often face academic, social, and personal challenges that can lead to high levels of stress. The pressure to meet academic expectations, deadlines, peer competition, and adapting to a new and demanding environment can all contribute significantly to stress.

This constant pressure can have repercussions on college students' mental health. The relationship between stress and mental health is reflected in an increased risk of disorders such as anxiety and depression, as well as in the exacerbation of pre-existing problems. Furthermore, academic stress can affect sleep quality, concentration, and decision-making, negatively impacting academic performance and overall quality of life.

## CONCLUSIONS

The average age of the students is 23.3 years, with a moderate range, indicating a wide variety of ages, which may influence differences in stress levels and mental health. The majority are men (67.7%), with a notable difference compared to women (32.3%).

Regarding academic stress: moderate and high stress levels are predominant in almost all age groups and semesters. In the early semesters, moderate stress is more common, while high and very high levels are more frequent in advanced semesters, particularly in the seventh and eighth semesters.

**Regarding eating disorders**: Moderate and low levels are the most prevalent across the majority of groups; however, "very high" levels are more frequent in advanced semesters. Similarly, comparable patterns are observed in both men and women, although women report a higher prevalence of moderate and low levels.

**In terms of mental health:** There is a relatively equitable distribution across the low, moderate, high, and very high categories. Women tend to report poorer mental health than men, which may correlate with their self-reported emotional levels.

However, no significant correlation was detected between these variables (Spearman's Rho = 0.003), suggesting that students' emotional levels do not necessarily translate into stress levels. Similarly, the correlation between stress and digestive disorders was not significant, indicating that academic stress does not directly impact digestive symptoms within this sample.

The results highlight the importance of implementing targeted interventions based on gender, semester, and age group. Strategies such as emotional wellness programs, stress management workshops, and psychological support services may be essential to address the specific needs of students at different stages of their academic journey.

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