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Computer-supported collaborative learning

Aprendizaje colaborativo en entornos digitales

Nuria Hernández-Sellés - *Centro Superior de Estudios Universitarios La Salle (Spain)*
Pablo-César Muñoz-Carril - *Universidad de Santiago de Compostela, USC (Spain)*
Mercedes González-Sanmamed - *Universidad de A Coruña, UDC (Spain)*
Coordinators of the Special Issue

ABSTRACT

In line with the requirements of a transformed industry, higher education has incorporated practices and tools allowing its students to apply technology to their professional practice. However, university commitment goes beyond facilitating technical skills, given that without a humanistic basis, those skills alone are not sufficient to meet the true challenges of the 21st century. Collaborative learning involves training for technology-mediated collaboration, and its pedagogical approach considers both the improvement of individual learning in contact with the group and the development of a culture of collaboration. The ability to collaborate is, in itself, typical of the 21st century. Both the field of higher education and the corporate environment recognize that collaborative learning tools are one of the three communication technologies that contribute most to university teaching. The challenges that go along with this involve training teachers, whose competencies conflict with university students' growing interest in making use of a technologically-mediated collaborative culture. Therefore, working collaboratively is particularly important when institutions, or teachers individually, want to adopt a humanistic culture in digital formats, proposing a documented framework supported by scientific evidence that addresses the intersection of knowledge, pedagogy and the group's socio-emotional level.

Keywords: collaborative learning; higher education; distance education; humanistic approach; group interactions.

RESUMEN

La educación superior, en coherencia con las exigencias de una industria transformada, ha incorporado prácticas y herramientas que permiten a sus discentes aplicar la tecnología a su práctica profesional. Sin embargo, el compromiso de la universidad va más allá de facilitar las competencias técnicas, dado que estas, sin una base humanista, son incompatibles con los verdaderos desafíos del siglo XXI. El aprendizaje colaborativo implica el entrenamiento para la colaboración mediada por tecnologías desde un abordaje pedagógico que se plantea tanto la mejora del aprendizaje individual en contacto con el grupo, como el desarrollo de una cultura de colaboración. En sí misma, la habilidad de colaboración es considerada como típica del siglo XXI y tanto el ámbito de la educación superior como el entorno corporativo, reconocen que las herramientas de aprendizaje colaborativo constituyen una de las tres tecnologías de la comunicación de las que se espera mayores aportes en las enseñanzas universitarias. Los retos que se presentan pasan por la capacitación docente, cuyas competencias entran en conflicto con el interés creciente de los alumnos universitarios por hacer uso de una cultura colaborativa mediada por tecnologías. Por tanto, el trabajo colaborativo toma una especial relevancia cuando las instituciones, o, individualmente, los docentes, desean adoptar una cultura humanista en los formatos digitales, proponiendo un marco documentado y sustentado en la evidencia científica que atiende a la intersección del conocimiento, la pedagogía y el nivel socioemocional en el grupo.

Palabras clave: aprendizaje colaborativo; educación superior; educación a distancia; enfoque humanista; dinámicas de grupo.

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INTRODUCTION

The paradigm of digital culture in the 21st century has brought about profound changes in how we organize ourselves as a society. These changes include the digitalization of economic and business practices that, nourished by the raw material of industry 4.0—data and information—have progressively reached into all areas of communication, including the private sphere (Srnicek, 2018; Saito, 2022).

Learning, and specifically learning in higher education, cannot be exempt from these practices, given the commitment to incorporating the professional dynamics of the systems in which graduates will be working. This means taking on the challenge of communicating, educating, and transferring knowledge in a different way to how it was done only 30 years ago. In line with the times and with the requirements of a transformed industrial sector, higher education has had to incorporate practices and tools that will allow graduates to apply technology to their professional practice. This transition is far from over, much work remains to be done, with studies indicating the current gap between informal and formal education, the clear challenge of continuing to train teachers, and students' growing interest in using social networks and collaborative videogames as educational tools in their university courses (Gómez-Aguilar et al., 2012; Pereira et al., 2019).

Furthermore, it is precisely those traits underlying contemporary digital society—linked to the mass, continual use of technology in all areas of activity—that require educational proposals combining a humanist approach with the technical skills that students already develop as part of their communication and learning culture. In this context, collaboration has become extremely important, and many authors have investigated its potential benefits and the conditions it needs. There is also broad accumulated experience of implementing it in various levels of education and for learning various materials and content (Piki, 2022; Yeşilyurt & Vezne, 2023).

Computer Supported Collaborative Learning (CSCL), in which small groups of 3 to 5 students tackle a complex challenge involving interaction over a limited time, incorporates the aforementioned aspects: the use of tools and collaboration with a humanistic approach. Considering how technology has acquired a prominent position in current educational proposals, CSCL no longer refers only to the virtual, but is instead found in hybrid and in-person teaching. Perhaps the initialism needs to be updated to reflect technology's prominence in education, broadening it out beyond exclusively virtual modalities and including other devices which are being used more and more often than computers. In any case, the key idea is to determine the many possibilities technology offers to provide collaborative learning, and in this regard, analyze the various components from design, execution, and evaluation of educational proposals. In addition, it is important to examine the various requirements that must be met (*technological*, related to the tools and applications to use; *pedagogical*, related to instructional design; and *relational*, dealing with formal and informal interactions along with the norms and relational culture produced) and the dimensions to consider (*cognitive*, related to the learning that takes place; *metacognitive*, referring to the possibilities of learning to learn that may arise; and *emotional*, to examine evaluations, feelings, and emotions at individual and group levels) (Asif Qureshi et al., 2021; Garrison et al., 2010).

This is the perspective from which the challenges identified in the paradigm of digital culture are addressed. Training for technology-mediated collaboration comes from a pedagogical approach that aims at both improved individual learning in contact with the group, and the development of a culture of collaboration. The ability to collaborate, in and of itself, is typical of the 21st century (Sobko, 2020), and various conceptual approaches—such as social constructivism; situated, shared, or distributed cognition; activity theory; and the sociocultural approach—support and sustain collaborative learning by fostering "constructed knowledge" as the result of joint reflection to agree and shape common meaning. The European Higher Education Area (EHEA) recognizes the need to develop skills for working in teams, for adapting to the flexibility of the job market, and increasingly group-based formats for projects, mediated by technology (Noguera et al., 2018). In addition, the report "The future of higher education: How technology will shape learning," sponsored by The Economist Intelligence Unit (Glenn & D'Agostino, 2008), which involved 189 higher education managers and 100 business managers, highlighted that collaborative learning tools were one of the three communication technologies that they expected to provide the most benefits to improving higher education.

The available research suggests that providing collaborative learning in virtual environments requires careful design of the technology-mediated collaborative experience, selection of a suitable project, proper use of the supporting technology, definition of the rules for collaboration or a collaboration guide, and an e-evaluation during and after the process. A well-executed design will encourage the groups to be able to self-direct their learning process, using the teachers as an additional means for consultation and support (Hernández-Sellés et al., 2014). However, achieving common goals requires the production of fruitful relationships and a fluid framework of interaction that contributes to creating and maintaining a united group. In this regard, studies indicate that social presence, in other words respect, recognition and intra-group emotional support, is as fundamental as the cognitive presence provided by each member's analysis to the group construction of the solution or the response to the problem (Borge et al., 2018; Xiulin et al., 2023). Hence the importance of taking care of the mechanisms for collaboration, agreeing on suggestions, sharing responsibilities, and envisaging common goals with regard to each team member's contributions and condition. The interaction must be considered from multiple perspectives (Hernández-Sellés et al., 2020): *cognitive* interaction, derived from working with the content, and the construction of knowledge between the students, as well as with the teacher; *social* interaction, between students and with the teacher; and *technological* interaction, with the interface, formal learning tools, or those chosen by the students (Wen, 2022).

Nonetheless, despite the abundant research about CSCL and the benefits of collaboration in learning contexts, implementation is still a challenge for universities. One of the challenges is teacher skills, as it is they who are responsible for putting these actions into practice, and because according to the CRUE and JRC analyses from the European Commission, as many as 41% feel they have insufficient digital skills. Added to that is the average age of university teachers, which the ministry responsible for universities puts at a mean of 55.8 years old. This suggests that higher education institutions face a significant challenge to adapt to their students' educational needs and learning styles.

In the specific case of collaborative working, the studies highlight the variety of roles teachers have to play in technology-mediated education. In addition to acting as subject-matter experts, their traditional role, they also have to play other roles that encourage deployment of skills for cooperation in a digital environment and which lead to the stipulated learning results. They must be teachers, evaluators, technical experts, guides/mediators, organizers/managers, they have to manage the social aspects of the group, and they have to provide a personal touch (Hernández-Sellés et al., 2023, Martin et al., 2021).

Working collaboratively becomes particularly important when institutions or the teachers individually want to adopt a humanistic culture in the framework of digital or technology-mediated education, proposing a documented framework backed by scientific evidence to combine curricular aspects, considering the intersection of knowledge, pedagogy, and socio-emotional level.

CONTRIBUTIONS TO THIS SPECIAL ISSUE

This special issue presents seven studies that address online collaborative working from various perspectives. The article entitled "Modelo de trabajo colaborativo online desde la perspectiva socioemocional", ["A model for online collaborative working from a socio-emotional perspective"] by Montalvo-García, Ávila and Longo, researchers from the Universitat Autònoma in Barcelona and the EAE Business School, uses a validated model to understand some of the factors that allow us to understand the dynamic work processes working in a team using a socio-emotional approach.

Martínez De Miguel López (Universidad de Murcia), Bernárdez-Gómez (Universidad de Vigo), and Salmeron Aroca (Universidad de Murcia) conclude, from a qualitative and phenomenological perspective, that integrating online collaboration tools among postgraduate students for academic activities underscores the importance of virtual environments in shaping meaningful interdisciplinary educational experiences and socialization; a factor that has been especially amplified during and after the pandemic.

From the Escuela de Posgrado Newman and the Universidad Nacional Jorge Basadre Grohmann in Peru, teachers Chura-Quispe, García Castro, Limache Arocutipa, and De La Cruz examine the creation and validation of a techno-pedagogical design with inverted learning and collaborative writing, indicating important factors about both aspects.

The researchers Reyes and Meneses provide an interesting view of collaborative learning from an inclusive approach in an online university —the Universitat Oberta de Catalunya (UOC)— unpicking the aspects that identify whether collaborative learning encourages inclusive processes.

From the Universidad de Santiago de Compostela, CSEU La Salle, and the Universidad de A Coruña, the researchers Muñoz-Carril, Hernández-Sellés and González-Sanmamed use a partial least squares model to analyze the factors that affect collaborative learning.

In an article entitled "Andamiaje docente para la construcción del conocimiento en el aula de investigación educativa" ["Teaching scaffolding for the construction of knowledge in the educational research classroom"], teachers from the Universidad de Granada Gutiérrez-Braojos, Rodríguez-Chirino, Pedrosa Vico, and Rodríguez Fernández, use a mixed methodology to look at the concept of "Collaborative Knowledge Building", digging into the understanding of teaching scaffolding that supports student knowledge building, as well as the strategies applicable to a range of collaborative constructivist learning environments.

Finally, UOC members Guitert Catasús, Romeu Fontanillas, Romero Carbonell, and Baztán Quemada, establish the validation of the ABPCL model for collaborative, online project-based learning.

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Online collaborative work model from a socio-emotional perspective

Modelo de trabajo colaborativo online desde la perspectiva socioemocional

Adolfo Montalvo García - *Universitat Autonoma de Barcelona, UAB (Spain)*
Santiago Ávila Vila - *EAE Business School (Spain)*
Frank Longo - *EAE Business School (Spain)*

ABSTRACT

It cannot be assumed that a group of students will automatically work collaboratively on an assignment. To facilitate this level of collaboration (so professors could evoke it) it is essential to understand how this academic interaction takes place. The purpose of this research is to validate a model of factors that provide us with an understanding, from a socioemotional perspective, of how students contribute to the dynamics of their group work. The sample is composed of 722 students from master's programs in management. The questionnaire utilized in this research was mostly comprised of items taken from highly recognized instruments measuring emotional intelligence. The proposed factors include: Self-control, Personal influence, Comprehensive communication, Teamwork, and Conflict management. A Confirmatory Factor Analysis was used to test the model. Significant differences were seen between females and Teamwork, Personal influence, and Comprehensive communication. Additionally, significance was evidenced between those over 30 years of age and Conflict management, Teamwork and Personal influence. The results provide insight into how to: a) elevate and improve this pedagogical dimension in higher education, and b) provide better guidance to students, allowing them the opportunity to improve their contribution to the teamwork they do and therefore increase the quality of their work.

Keywords: teamwork; emotion; self-control; social influence; communication; conflict.

RESUMEN

El hecho de que un grupo de estudiantes *online* trabaje de forma conjunta en un cometido académico no es sinónimo de que lo hagan colaborativamente. Para que los alumnos se puedan desempeñar de esa forma (y que los profesores la puedan llegar a evocar), obteniendo así unos mejores resultados de su aprendizaje, resulta imprescindible comprender cómo se sucede esta interacción académica. La finalidad de esta investigación es validar un modelo de factores que permita entender cómo aportan los estudiantes a sus dinámicas de trabajo en equipo desde una perspectiva socioemocional. La muestra está compuesta por 722 estudiantes de masters de *management*. *S*e cursa un cuestionario que está integrado en su mayoría por ítems extraídos de instrumentos que son referente de la medida de la inteligencia emocional. La propuesta de factores se concreta de la forma siguiente: Autocontrol, Influencia personal, Comunicación integral, Trabajo en equipo y Gestión de conflictos. El modelo obtenido se comprueba ajustado mediante Análisis Factorial Confirmatorio. Se observan diferencias significativas entre sexo femenino y Trabajo en equipo, Influencia personal y Comunicación integral; así como entre mayores de 30 años y Gestión de conflictos, Trabajo en equipo e Influencia personal. Los resultados arrojan luz sobre como: a) plantear y mejorar esta dimensión pedagógica en la universidad; b) procurar una mejor orientación al alumnado para que este mejore su particular contribución a los trabajos de equipo.

Palabras clave: trabajo en equipo; emoción; autocontrol; influencia social; comunicación; conflicto.

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INTRODUCTION

Face-to-face teamwork is already complicated, but conducting it online adds further to that complexity. Online learning does not offer a natural and immediate possibility of redirecting emotions in an emotionally intelligent way as can be done in face-to-face learning when moments of tension occur. Furthermore, in this type of training, the interpretations that each person makes of what is happening leads to errors in the common establishment of causes and work patterns (Järvelä & Bannert, 2021). In a university environment, poorly managed teamwork leads to frustration and stress (Bourner et al., 2001). Currently, there is still a need for a development of greater knowledge and better tools that allow students to enjoy more appropriate social and emotional support (Saccardi & Masthoff, 2023).

The more common behaviors exhibited in a university setting aligns with the type of interaction that regularly occurs between any individual and their environment. The diversity that occurs in any group (e.g., culture, gender, age, education, political preferences, or social influence on others), can lead to the formation of smaller subgroups (Saccardi & Masthoff, 2023). These subgroups are based on the socio-emotional bonds established by group members (Huang & Lajoie, 2023). In collaborative learning, social-emotional exchanges play a fundamental role in shared social regulation (Nguyen et al., 2023), therefore contributing to the maintenance of healthy positive emotional relationships (Huang & Lajoie, 2023). Helping others and providing information are behaviors that foster interactive social presence and result in greater emotional co-regulation (Huang & Lajoie, 2023). The quality of the social-emotional interactions has an impact on collaboration and academic results (Zhang et al., 2021), while cause-emotions could trigger other emotion-effects. In turn, those ensure that progress can be made towards the objectives set in the collaborative task (Järvenoja & Järvelä, 2005). Groups of students who nurture the socio-emotional dimension of their interaction stay cohesive and ensure that the relationship is respectful (Rogat & Adams-Wiggins, 2015).

Positive socio-emotional interactions that are generated in a group condition incline the collective to perceive its own members as better collaborators, while encouraging the team to work as a community (Zhang et al., 2021). Therefore, more continuous and fluid regulation occurs in a high-performing team compared to a low-performing group, where there is a tendency for repeated regulatory behavior (Su et al., 2018). What emerges are respect, mutual support and dedication, as indispensable conditions for community work (Rogat & Adams-Wiggins, 2015). Close relationships among group members can foster a culture where empathy is valued and appreciated, resulting in a higher level of commitment (Yu et al., 2023). The present research proposes a model that takes into account the individuality of each student in a team, since many of the challenges that are linked to successful team development occur due to the attitudinal predisposition of its members (Saccardi & Masthoff, 2023). The emotional dimension does not escape the Input-Process-Output model, where an emotional input will condition the outcome of the process faced by the group, and finally the output achieved (Bonny, 2023). Where students who are competent leaders contribute to peer interaction thus contributing to a harmonious learning atmosphere and group cohesion the ultimate result can be found in better academic performance and learning satisfaction (Huang et al., 2010). From a socio-emotional perspective, being a good team member means complying with all the proposed factors, since people are constantly looking for social support, especially in situations of greater difficulty, such as those in an academic setting. (Saccardi & Masthoff, 2023).

Proposed factors

The first factor considered corresponds to Conflict Management. In teams, three types of conflict are identified: relational conflict, when there is interpersonal tension among team members; process conflict, when there is no quorum on how to distribute work and resources; and task conflict, which takes the form of holding different opinions on how to do the work. From this triad, relational conflict most directly affects the functioning of the team (Baird & Benson, 2022) since it lowers morale and makes it difficult to focus on the work to be done. This ultimately means lower satisfaction and performance. Having a reputation as an effective leader and follower is negatively related to being seen as a creator of conflict within the team. Individuals who establish a reputation for collaborative and cooperative interpersonal behavior are less likely to be involved in subsequent negative interactions. On the other hand, dysfunctional leader-follower dynamics have the potential to derail team functioning and create a toxic social environment (Baird & Benson, 2022).

A second factor, Personal Influence within the team, emphasizes the contribution of each person to the collective, which is enhanced by each member shining individually. This contributes from both intrapersonal and interpersonal perspectives (Gardner, 1983). This factor also has to do with helping others to effectively manage their experience (Wetcho & Na-Songkhla, 2022). This is done in such a way that the emotional connection between the members of a team ends up shaping the perception of the work environment, while influencing the emotional expressions that follow in a dynamic way. From the literature, the concept of Early Active Collaborator is designated to those team players who foster a sense of community, who share their problems, and who develop social bonds with the rest of the members (Huang & Lajoie, 2023). Wang et al., (2022) concluded that workers with high interpersonal influence are more likely to develop psychological safety, which subsequently makes it easier for them to deal with problems.

The third factor of the proposal is Comprehensive Communication, which is key to reaching deep learning through the serene and calm presentation of the different alternatives and analysis presented by the team members (Blau et al., 2020). Additionally, Montalvo-García et al., (2022) present a Comprehensive Online Communication Model that considers verbal and nonverbal dimensions as complementary in the creation of knowledge within the framework of constructivist paradigms. In this sense, emotional support also includes the type of communication that is aimed at helping others to manage their negative emotions (Burleson, 2003). Communication between collaborators becomes a very relevant issue since virtual teams are subject to long waiting times which are a result of their asynchronous nature (Yu et al., 2023). This awakens in the expectant student different types of emotions, as well as multiple interpretations of what may be happening until an answer is obtained. Likewise, it plays a decisive role in the synchronous part of online training, since the facial expressions of the colleagues collaborating virtually in real-time function as important emotional inputs of nonverbal communication (Bonny, 2023).

The fourth factor corresponds to Self-control, which is key when facing demanding social situations. Online students with high self-control have the ability to modulate the attention of their academic experience in an intelligent and advantageous way (Montalvo & Ávila, 2023). Transmitting calmness, instead of negative emotions, to others is a valuable contribution, as it contributes to team balance. Therefore, Self-control is a socio-emotional competence present in the practice of all theoretical models. The most common form of emotional regulation is called “poor”, which in professional environments corresponds to the manifestation of the external suppression of emotion (Gagnon & Monties, 2023). That leaves the person feeling uncomfortable which will affect their future involvement in the team, and subsequently in their results. Self-control has other expressions beyond a timid personality that avoids defending one's own interests (poor category) and is then recognized as one of the constituent elements of self-leadership (Goleman, 1999).

The fifth factor encompassed in this proposal is Teamwork. Montalvo and Ávila (2023, p. 124) define it as the "cooperation with others, contributing to maintain adequate relationships for online teamwork”. Therefore, collaborative teams need to incorporate trust and cohesion into their processes to achieve intended goals, as well as nurturing relationships (Montalvo & Ávila, 2023), ones that are seen when the group shares in the success of each individual and sees it as good for the collective (Mesa Rave et al., 2023). Traditional leadership studies focused on the study of specific individuals identified as leaders. However, from a social psychology perspective, there is also a growing trend in addressing the issue of shared leadership, when exploring the dynamic exchange of the leader's role within a team (Baird & Benson, 2022). In our complex and changing environments, shared leadership is a necessity to be able to embrace diverse perspectives, dynamics that a sole leader could not handle. In the shared leadership model, the power and knowledge are shared among the members of the group. Leveraging the contributions of each of the members results in greater innovation. Baird and Benson (2022) support the idea that follow-up is a necessary component of the shared leadership model. It is useless to produce proposals that are not implemented; moreover, implementation without reflection doesn’t contribute to learning. From this perspective, mutual exchange of influence will only work if the members are committed to allowing themselves to be influenced. Analyses of social relationships reveal that shared leadership occurs when a teammate is seen as both an effective leader and effective follower (Baird & Benson, 2022).

METHOD

Participants

The questionnaire was completed by 722 students. The mean age of the sample was 30.62 years; 385 (53.3%) were female and 337 (46.6%) were male. In relation to age distribution: 181 students were under 26 years old (25%); 217 students were between 26 and 30 years old (30%); 167 students were between 31 and 35 years old (23.1%); 87 students were between 36 and 40 years old (12%); 42 students were between 41 and 45 years old (5.8%); and 28 students were over 45 years old (3.8%). Analyzing country of origin yielded: Spain, 267 (36.9%); Peru, 114 (15.7%); Colombia, 95 (13.1%); other Spanish-speaking countries in the Americas, 215 (29.7%); other European countries, 19 (2.6%); and other countries in the world, 12 (1.6%).

Instrument

Table 1 is composed of essential items from instruments that are considered as benchmarks in Emotional Intelligence. Only two items related to giving feedback are provided, since this issue was not covered by the existing questionnaires already mentioned. Table 1 reports the factors, their constituent items, as well as their origin. Consistent with all the questionnaires cited in this work, the resulting questionnaire falls into the category of self-reported instruments, where the student responds by carrying out a process of personal introspection. It was prepared using a Likert scale 1-10, where 1 means "Strongly disagree" and 10 means "Strongly agree".

Table 1
Factors, Items and Their Origins

Factor	Ítem	Origin of the Instrument
Self-control	I can stay calm with I'm upset.	Bar-On, 1997
	I'm a self-controlled person.	
	It's easy for me to relax.	Bisquerra & Pérez-Escoda, 2007
	When my mood isn't too good, I try to do activities that I find enjoyable.	
	When I overthink things, complicating them, I try to calm down.	Fernández-Berrocal et al., 2004
Personal Influence	I tend to encourage others.	Goleman et al., 1999
	I am able to influence other people's feelings.	Petrides, 2009
	People trust me easily.	Schutte et al., 1998
	In my life, I develop satisfactory social relationships, on which affection can be inferred.	Bar-On, 1997
	It's easy for me to notice how others are feeling.	Bisquerra & Pérez-Escoda, 2007
Comprehensive Communication	When I see someone doing something wrong, I'm able to help them by talking to them so they can get better.	Own items
	I am good at giving *feedback*, even when it's negative for the person receiving it.	
	I am aware of the non-verbal information I convey to others.	Schutte et al., 1998
	I make a good gesture to convey my meanings.	Fitzgerald, 2013
	I can give good answers to difficult questions.	Bar-On, 1997
Teamwork	I tend to strengthen cooperation and that makes me a good team player.	Goleman et al., 1999
	I am very clear about I want and I share it with others.	Bar-On, 1997
	I am glad to do things for others.	
	I am a collaborator in the groups I'm in.	
	I am flexible to change my behavior by adapting to new situations.	
Conflict Management	In general, I am able to cope with stressful situations.	Petrides, 2009
	I consider myself a good negotiator.	
	When I have a positive attitude, solving problems is easy for me.	Schutte et al., 1998
	I don't give up on a problem until I solve it.	Bar-On, 1997
	I tend to make it easy to resolve disagreements.	Goleman et al., , 1999

The instrument also included control variables: sex and age, which were coded as dummy variables: female=1, male=2; equal to or younger than 30 years old=1, older than 30 years old=2.

Procedure

In September of 2023, management students enrolled in online programs from EAE Business School, with campuses in Barcelona and Madrid and accessed a digital questionnaire through a voluntary response link. It was distributed at the end of an Introductory Workshop, that marks the beginning of their studies. The workshop focused on two items: a) the constructivist pedagogical model of training, requiring students to collaborate both in the synchronous and asynchronous stages of teamwork, and b) the importance of social learning and collaboration in management studies, considered within the field of Social Sciences.

Data Analysis

Compliance with the normality condition was analyzed by means of the absolute values of symmetry, between 0 and 2, and kurtosis, between 0 and 7, which provide evidence of a normal distribution (Curran et al., 1996).

The goodness of fit of the model was calculated from the chi-squared ($\chi 2$)/DF index (in AMOS: CMIN/DF); the values considered adequate are within the range 2:1 or 3:1, between the sample size and the degrees of freedom. In turn, the RMSEA index determines the covariance structures, resulting in a good fit when it is situated at values below 0.08. For its part, the GFI index, on the goodness of fit in the variance-covariance ratio, recommends values above 0.90. Finally, the PGFI or parsimonic goodness-of-fit index was calculated, which considers values above 0.60 to be adjusted, since they show good parsimony (Montalvo & Ávila, 2023).

In addition, the reliability of the factors was also estimated with Cronbach's α, with α values between 0.7 and 0.9 being accepted as indicators of good internal consistency (Montalvo & Ávila, 2023). To test the theoretically predicted relationships, SPSS 24 and SPSS Amos 25 were used, with the maximum likelihood option in the case of Confirmatory Factor Analysis (CFA).

RESULTS

Descriptive Statistics

The absolute values of symmetry and kurtosis are within the referred intervals (0-2 for symmetry and 0-7 for kurtosis), which makes possible the use of parametric tests (Curran et al., 1996). Table 2 presents the means, standard deviations, correlations and significance levels between variables. It can be seen that the control variable sex, correlates with Teamwork ($r = -0.17$, $p < 0.01$), Personal Influence ($r = -0.16$, $p < 0.01$), and Comprehensive Communication ($r = -0.21$, $p < 0.01$). Additionally, the variable age shows significant differences with Conflict Management ($r = -0.17$, $p < 0.01$), Teamwork ($r = -0.10$, $p < 0.01$), Self-control ($r = -0.10$, $p < 0.01$), and Personal Influence ($r = -0.08$, $p < 0.01$). It is important to note that the correlations between all the variables included in the theoretical proposal of this study always present a high significance between them.

Table 2
Descriptive Statistics and Correlations

	Average	DE	1	2	3	4	5	6	7
1. Sex	1,46	,49	1	-,018	-,054	-,177**	-,036	-,163**	-,209**
2. Age	1,44	,49	-,018	1	,171**	,102**	,097**	,082**	,065
3. Conflict Management	42,42	4,93	-,054	,171**	1	,640**	,535**	,562**	,469**
4. Teamwork	42,43	5,04	-,177**	,102**	,640**	1	,672**	,612**	,457**
5. Self-control	38,46	6,72	-,036	,097**	,535**	,672**	1	,451**	,381**
6. Personal Influence	33,46	3,86	-,163**	-,163**	,562**	,612**	,451**	1	,492**
7. Comprehensive Communication	36,03	5,21	-,209**	-,209**	,469**	,457**	,381**	,492**	1

Note: **p < 0.01

Confirmatory Factor Analysis

Table 3 provides a summary of the fit of the three models used. It is based on Gardner (1983), who distinguished for the first time between the intrapersonal and interpersonal planes, providing a more comprehensive perspective of people's performance. Combining the Teamwork and Conflict Management factors into a single factor, results in a 4-factor model that corresponds to M2. Conversely, to conceptualize M3, the intrapersonal factors (Self-control, Personal Influence and Comprehensive Communication) are amalgamated into a single factor.

Table 3
Summary of Fit Indices of Structural Equation Models

Model	Description	χ^2	gl	CFI	GFI	PCFI	RMSEA
M1	Model with 5 factors	720,082	256	,915	,921	,781	,050
M2	4-factor model; Interpersonal Factor + Self-Control + Personal Influence + Comprehensive Communication	755,826	260	,909	,918	,788	,051
M3	Model with 3 factors; Intrapersonal factor + Teamwork + Conflict Management	939,050	263	,876	,893	,768	,060

Although both M1 and M2 present an adequate fit, M1 corresponds to the model that presents the best indicators in the CFA (Chi-square = 720.082; Degrees of freedom 256; CFI 0.915; GFI, 921; PCFI 0.781; RMSEA 0.050). Consequently, this model is selected as it empirically reports the best adjustments to the theoretical proposal included in this research.

Finally, the results of Cronbach's alphas (α) confer reliability to M1, although the Personal Influence factor is very slightly below 0.7, specifically at 0.687. The rest of the factors do lie above the 0.7 as follows: Comprehensive Communication 0.724; Self-control 0.723; Conflict Management 0.703; and Teamwork 0.721.

DISCUSSION

The results of this study highlight which socio-emotional factors affect the collaborative dynamics of students enrolled in an online educational program. These dynamics are usually overlooked by professors, even though the effectiveness of academic work is related to a well-executed process, in which greater cohesion among group members leads to better results (Beal et al., 2003). Therefore, the model obtained in this study broadens the range of possibilities for working on the socio-emotional dimension of online collaborative learning.

On the other hand, Huang and Lajoie (2023) in a meta-study conclude that the most frequent way to measure these results is through qualitative studies. That involves coding students' behaviors from video recordings or from the interpretation of their asynchronous communication, combined with self-reported questionnaires. In this sense, the present work provides a model consisting of the following factors:

A. Conflict Management
B. Emotional Self-control
C. Personal Influence
D. Comprehensive Communication
E. and Teamwork

From a socio-emotional perspective, this model offers a good fit and makes it possible to evaluate the level of collaboration from each member of a remote team. At the same time, it also overcomes the difficulty pointed out by these authors on how to replicate the codes of interpretations in subsequent studies with larger and geographically different populations.

A. Analyzing the Conflict Management factor. From an emotional perspective, this model can be used to understand how existing work dynamics present problems from the outset. This model can also be used to proactively detect when group processes begin to deteriorate or lose cohesion, which allows for the identification, interpretation and avoidance of socio-emotional problems that may present as teams progress in achieving an academic goal (Bonny, 2023). When working in a team, it is common for one or more students to report that members are not displaying appropriate attitude or behavior consistent for collective responsibility. Having a socio-emotional model that defines the appropriate characteristics for collaboration is crucial, as it identifies which behaviors should be observed and implemented for the effective development of the academic process. By reinforcing a committed and collaborative culture, disruptive students ('bad apples') (Baird & Benson, 2022) will find it more challenging to derail the team dynamics. The goal is to reduce the number of disruptive students who display toxic behaviors – such as not being punctual, skimping on effort, spreading a negative attitude, and not fulfilling what has been agreed upon – thus enhancing the overall effectiveness of the team.
Incorporating Conflict Management, a critical and unavoidable dimension in small teams, into this model clarifies realistically its importance to students. Team members emotionally experience disagreements within their groups, leaving them unable to integrate differing personal perspectives on immediate actions or ongoing problems they are facing (Näykki et al., 2014). Likewise, the

model also illustrates how positive social interaction helps to eliminate disagreements and encourages team collaboration, resulting in increased commitment when facing difficulties (Hu et al., 2021). Ultimately, metacognitive awareness about the existence of functional and dysfunctional conflicts contributes to experiencing problems as natural and essential, fostering a collective effort to emerge stronger. By remaining united, teams are able to overcome difficulties and become stronger, as seen in the constructive conflict (Baird & Benson, 2022). Online collaborative work at university is no exception to the Tuckman Model (Zirar et al., 2023), which states that to operate as a high-performance team, members will always need to overcome their own storms (storming stage). In this sense, research confirms how conflicts become beneficial with proper emotional regulation (Griffith et al., 2014).

B. On the other hand, in relation to emotional Self-control, it contributes to good work dynamics where reason dominates emotion. These two dimensions flow in parallel and reciprocally reinforce each other, with an essential requirement being that reason dominates in academic work. These results make it possible to extend the literature that already establishes that shared emotional regulation by team members promotes positive socio-emotional interactions leading to improved performance (Kazemitabar et al., 2022). Zhu et al. (2020) point out the importance of managing social interactions in an online training modality. They highlight that information on this factor is essential to anticipate the attitude of students and predict how they will approach their academic work in the online part of the curriculum, where the professor is present virtually. The university should also provide a space where students can demonstrate their responsibility, for example, through conscious and well considered decisions, or by staying focused on their academic tasks beyond possible distractions. Additionally, this environment should be making it possible to progress in socio-emotional competencies such as Self-control, a key in self-leadership and recognized in the European Higher Education Area as generic or transversal competencies (Montalvo-García, 2021). Self-control is also crucial in any facet of life beyond university.

C. The Personal Influence factor is the determining factor in team dynamics. Individuals who create a positive motivational climate and offer strong support for their teammates are valued. Their ability to collaborate and overcome obstacles during the most intense periods of academic work is recognized and valued. The motivational climate of a professional team is a decisive factor in its creativity (Zhao et al., 2023). In the same way, it appears evident that university academic teams also benefit from Comprehensive Communication. Adding the socio-emotional perspective fosters harmony. That harmony facilitates a better disposition to the work satisfaction and directly correlates to higher quality results. Likewise, when individuals feel motivated and valued, it is easier for them to share their ideas, knowledge and resources, contributing to originality and innovation. This promotes a strong sense of belonging and emotional bonding. Zha and Ottendorfer (2011) found that those students who served as leaders in collaborative work were more cognitively active than the rest of the members in online discussions. A good motivational climate creates an environment of trust and shared respect, where the members perceive the team as a whole and expect them to work ethically. Furthermore, this key factor of the model obtained is valuable, since an adequate motivational climate contributes to the reduction of internal conflicts, mitigating tensions and enhancing the team's capacity to handle disagreements in a constructive manner.

D. Regarding the factor of Comprehensive Communication, this factor being part of the model obtained correlates with previous research that establishes a relationship between communicating in an appropriate manner and the achievement of the intended objectives (Kazemitabar et al., 2022). Comprehensive Communication is the main tool that teams use to reach academic goals. It encompasses not only the transmission of content or the exchange of information, but also the creation of cognitive and social links (Mesa Rave et al., 2023). In the present study, this factor (and therefore in the Model) captures information about expressing oneself adequately, defending one's own ideas assertively, and displaying empathetic listening to the rest of the teammates. The nonverbal part is key when interpreting the phenomenon that occurs when a group of students collaborate virtually. Understanding the communicative act as a complex process, in the online modality, can be explained by seven factors: conscious direction, self-efficacy, positive affect, emotional regulation, empathy and feedback, influence and assertiveness, and transcendent leadership (Montalvo-García et al., 2022). Therefore, both synchronous and asynchronous e-contacts define the degree of understanding among the members of a team (Montalvo-García et al., 2022). They enhance the academic process and the results reached by the teams. Communication is the tool to make oneself understood, a necessary preliminary step. It allows colleagues to complement our proposal with their part of the work or to understand precisely what our colleagues expect from us; in other words, to make progress. In short, it is a matter of creating a space for virtuous work (Aristotle).
E. The last factor included in the validated model is Teamwork. The results of this study coincide with Contreras et al. (2020) who conclude the need for the members of a remote online team to coordinate in a well-aligned manner with a shared purpose. This type of collaboration makes it possible to overcome geographical barriers and collaborate with colleagues spread halfway around the world. In this research, the international sample is composed mainly of students from multiple Latin American countries, where it is necessary to overcome the difficulty of having to cooperate in different time slots and from culturally diverse backgrounds. Successfully completing a process of this nature results in personal enrichment, while providing students with experience in the global professional environment which is characteristic of the dynamics of the contemporary working world, which in many cases involves the same collaborative and communication tools, along with obvious project management similarities. Properly conducted, online teamwork should draw from different perspectives around the world. According to the constructivist paradigm, this approach leads to a richer learning experience.

In relation to the control variables included in this study, the results show that the female sex scores were significantly higher in the factors, Teamwork and Personal Influence. This is consistent with the literature that establishes higher levels of emotional intelligence oriented to transformational leadership (Hsu et al., 2022). Where shared common goals are required, there is a higher degree of collaboration working virtually, as well as a greater willingness to actively participate in virtual teams. Additionally, women also communicate comprehensively with significant differences which translates into increased empathy with others, along with a greater orientation to relational communication.

On the other hand, significant differences have been identified between the group of people over 30 years of age and Conflict Management. It can be interpreted that having greater experience and going through more difficulties in life led to a more mature and balanced approach. Likewise, a longer life means exposure to more diverse opinions and ways of thinking, which can translate into greater tolerance and respect for others. Over the years, one gains resilience and patience, which provides the calmness necessary to constructively address problems in tense situations. Furthermore, the sample group composed of those over 30 years of age correlates significantly with the Teamwork and Personal Influence factors. This finding aligns with the idea that a team with more experience understands better the benefits of collaboration compared to a younger and inexperienced team. They can express ideas clearly and listen assertively, taking into account the perspectives of others during the academic collaborative process, contributing to the common good and the team's progress. The experience usually goes hand in hand with a sense of commitment and responsibility. Significant differences are also identified between those over 30 years of age and Self-control, a trait that can be acquired from experience in managing complicated situations. Each experience involves experiential learning and gaining in the development of more advanced emotional skills. Greater emotional awareness contributes to the ability to manage emotions more effectively by avoiding impulsive reactions and focusing on long-term goals. More experience contributes to better handling of ambiguity and uncertainty in a more constructive way.

Future research should verify whether the results of this study can be extrapolated beyond the world of Spanish-speakers, given that underlying there is a very similar cultural substrate that may not be replicable in another cultural environment. That may require specific refinements. Likewise, they may complement the model (M1) reported in this study with software that makes it possible to collect data on facial expressions, head movements, gestures, postures, or tone of voice (Huang & Lajoie, 2023). It is agreed that future research should shed light on the dynamic patterns of socio-emotional interactions (Huang & Lajoie, 2023), beyond an individual approach, like the one presented. It is necessary to continue investigating how socio-emotional awareness is formed and how emotional regulation develops at team level (Huang & Lajoie, 2023).

CONCLUSIONS

Being an online student presents a different way of collaborating when working as a team. Synchronous and asynchronous technology-mediated interactions, change both the connection and the emotional management of students. In this sense it is necessary to know in more depth how these remote work dynamics can be optimized to propose a better educational experience and enhanced learning. The results of this research conclude two main findings: a) A model that allows us to realize what socio-emotional characteristics each student should have based on the factors that promote being a good team player. In this subsidiary way it will be possible to diagnose the degree of development of each member. b) From an organizational point of view, this can contribute to the design of training programs that give more consideration and encouragement to students. Universities must pay more attention and monitor more seriously what happens with team dynamics. It is a fundamental part of the curriculum offered, in addition to the fact that it can become fundamental training for the professional future. Its students, who upon finishing university, will join a complex, digital labor market with increasingly flatter structures and so knowing how to collaborate virtually becomes an essential dimension for any professional.

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Retrospective analysis for the perception of educational tools for the development of collaborative activities in virtual environments

Análisis retrospectivo de la percepción sobre herramientas para el desarrollo de actividades colaborativas en entornos virtuales

Silvia Martínez De Miguel López - *Universidad de Murcia, UMU (Spain)*
Abraham Bernárdez-Gómez - *Universidad de Vigo, UVigo (Spain)*
Juan Antonio Salmerón Aroca - *Universidad de Murcia, UMU (Spain)*

ABSTRACT

Virtual learning environments are technological systems designed to use electronic media to enable non-face-to-face education and interaction between students to take place. The research presented here considered six academic years and was carried out against the backdrop of the impact that these environments are having on higher education. It used a non-experimental, retrospective, cross-sectional approach, and was conducted within the qualitative phenomenological paradigm. The participants were 211 students who were engaged in an online postgraduate course. The aim was to identify the benefits and difficulties the students encountered when they used collaborative tools in their learning process, and the group dynamics that were established. Portfolios, forums and focus groups were the mechanisms used for data collection. The results showed a great diversity in how digital tools were used, how they were adapted to the complexity of the virtual classroom and the multi-professional profile of the participants. However, in general, the participants displayed a strong need for connection in order to share their concerns, develop bonds and build collective knowledge. There was greater emphasis on collaborative tasks during and after the pandemic than in previous periods. It was concluded that the integration of online collaboration tools among postgraduate students to carry out academic activities reflected the key role that virtual environments play in the shaping of meaningful interdisciplinary and socialisation educational experiences. In addition, the role of the group's own self-regulation in terms of maturity, networking, chronological adjustments and understanding of the task at hand was essential in the participants' ability to overcome the challenges they encountered.

Keywords: educational tools; online higher education; virtual learning environments; online colaborative learning; educational technology.

RESUMEN

Los entornos virtuales de formación son sistemas tecnológicos diseñados para facilitar la educación no presencial y la interacción entre estudiantes, a través de medios electrónicos que están teniendo impacto en la educación superior. La investigación que se presenta fue desarrollada mediante un enfoque no experimental de tipo transversal retrospectivo. Anclado en el paradigma cualitativo fenomenológico, se involucró a 211 estudiantes de posgrado en línea de seis años académicos, con el objetivo de conocer los beneficios y dificultades que encuentran en el proceso formativo a través del uso de herramientas colaborativas y las dinámicas de grupo que se establecen. Se emplearon portafolios, foros y grupo de discusión. Los resultados revelan una diversidad en el empleo de herramientas digitales, adaptadas a la complejidad del aula virtual y al perfil multiprofesional de los participantes. Sin embargo, de manera general, muestran una marcada necesidad de conexión para compartir inquietudes, establecer vínculos y construir conocimiento colectivo. También es notable que, durante y después de la pandemia, se observa un mayor énfasis en las tareas colaborativas en comparación con períodos anteriores. Se concluye que la integración de las herramientas de colaboración en línea entre el alumnado de posgrado para la realización de actividades académicas, refleja la importancia de los entornos virtuales para la configuración de experiencias educativas significativas interdisciplinares y de socialización. Además, el rol que cumple la autorregulación del propio grupo para su uso, en términos de madurez, redes vinculares, ajustes cronológicos, y comprensión de la tarea, es fundamental para superar las dificultades que encuentran.

Palabras clave: herramientas educativas; educación superior *online*; entornos virtuales de aprendizaje; aprendizaje colaborativo en línea; tecnología educacional.

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INTRODUCTION

The foundation of this research lies in the change experienced in teaching-learning processes as a result of the emergence of virtual universities in the 1990s (Rubia & Guitert, 2014). The increasing use of technology and the digitalisation of teaching have since become well-established. Despite this, the educational policies that contribute to achieving digital competence remain underdeveloped and lack maturity (Castañeda et al., 2023; Férnandez Miravete & Prendes Espinosa, 2022). The advent of lockdown as a result of the COVID-19 pandemic was a turning point in the use of resources and technological platforms. The situations derived from the pandemic set the groundwork for the widespread use of distance learning resources and technologies, and the stigma of their being second best when compared to face-to-face learning has been laid to rest (Carafi, 2022; Ruiz Corbella et al., 2011). In line with these developments, Fernández Sánchez et al. (2021) noted an upturn in student preferences for virtual and blended modalities in undergraduate and postgraduate studies (Esteban et al., 2020; INE, 2022). This has also contributed to universities being able to maintain enrolment rates for some postgraduate courses (Ministerio de Universidades, 2022).

Consistently with the above, one of the starting assumptions for this study is that online learning has a well-established methodology and digital availability of its own. Consequently, the scope of teaching and the academic outcomes were not significantly affected by the adaptation processes that face-to-face learning experienced in the context of higher education due to the pandemic (UNESCO, 2020). However, there are some related consequences and issues that have led to the emergence of new needs and questions from within the academic sphere: What are students' perceptions of their own command and knowledge of computer-assisted collaborative learning tools? What is their assessment of this? Do they feel interested in and motivated by them? These consequences should be explored further and would also support the research presented here.

The rationale for this research was based on two needs. Firstly, postgraduate students' perception of collaborative activities in virtual environments. An approach derived from the development and positioning of this type of training since the Bologna Declaration of 1999 (Docampo, 2001; RD 56/2005).

Secondly, considering the pandemic as a key event in the digitisation of university education, two questions need to be explored. These questions were, on the one hand, the use of digital platforms and educational technology tools in teaching nowadays (Sánchez Vera, 2023) and, on the other, an analysis of the studies that have highlighted some problems such as the digital divide and the lack of social interaction (Piki, 2022), which negatively affect students. These phenomena will represent one of the main challenges for education in the next decade (UNICEF, 2022), and it is therefore necessary to understand the impact that these social factors currently have on the theory of online collaborative learning (Asif et al., 2021).

The visibility of these needs points to the multifaceted nature of the meaning of the term 'collaborative online learning' (Harasim, 2012). This is linked both to the variety of institutions that offer it at different education levels, the diverse roles it affords to teachers' performance, and the different teaching models that support it, including how these are assessed. This is why the last few decades have seen important developments in the study of collaborative learning through technology in the field of social sciences (Anwar et al., 2023; García Chitiva & Suárez Guerrero, 2019; Janssen & Kirschner, 2020; Lämsä et al., 2021). Concurrently, there has been a proven increase in the motivation and interest of social science students in the use of ICT (Salas Rueda et al., 2020). This interest has not so much been in these technologies per se but in the way in which they are used (Valencia & Rodríguez, 2019). By way of illustration, the advantages of online collaborative learning include its contribution to improving students' cognitive performance and enhancing their interpersonal communication (Tusyanah et al., 2023). Despite the above-mentioned benefits, this type of learning may also display less beneficial characteristics, such as participatory inequality, conflict-ridden situations and time requirements (Aguilera, 2023).

From this point of view, the joint construction of knowledge involves establishing a fluid interaction for group cohesion. If these variables are not taken into account when promoting meaningful interaction within the group, there is a risk that the students' end-to-end learning experience will be negative (Hernández Sellés, 2021). According to this perspective, students need to learn to collaborate in order to learn (Leiva Reyes et al., 2020). Therefore, one of the related problems is that attention should not only be focused on the learning situation or on interpersonal interactions in isolation, but that both should be made available as learning mechanisms with an impact on students (Mercado Borja et al., 2019). While field research on these aspects in higher education is not new (Alfageme, 2005; Rodríguez Illera, 2001), this study seeks to place them in a temporal context. Within this viewpoint, the research focuses on answering the following question from the students' perspective: How have collaborative learning activities (conceived as methodological tools) contributed to online teaching in recent years?

METHODOLOGY

Objectives

The overall aim of this article was to analyse the students' perception of how collaborative learning activities as methodological tools in virtual environments can make a contribution to online higher education. There were three specific objectives:

1. To analyse the benefits and difficulties identified by postgraduate students in the tools used in online collaborative methodological processes.
2. To study and analyse the benefits and difficulties encountered during activities that involved the use of these tools.
3. To describe the comparative experience of their use among students from a time perspective and taking into account their marks in the subject.

Design

A retrospective cross-sectional study was conducted that used the phenomenological approach of the qualitative paradigm (Bisquerra, 2016). The basis for this approach is based on the individual's experience of an event or a set of events and the meaning that these events have for the subject (Flick, 2015). An inductive design was chosen in order to include the students' own point of view. As this was a retrospective phenomenological study covering several recent academic years, it provided a perspective on the variability of contributions over time. Specifically, students who had taken the online Master's programme in Museums over the last six years were included in the sample.

Prior to the start of the research, the Ethics Committee of the University was informed of the purpose of the study, and provided a favourable response and approval for carrying it out (ID: 4707/2023).

Research context

The research was carried out in the context of the Master's Degree in Education and Museums: Heritage, Identity and Cultural Mediation (eMus). The eMus course was initially taught using the free software platform Sakai, where students could access, create and post theoretical content, complete practical activities, interact with teaching staff through synchronous and asynchronous communication tools such as email, forums, messages, videoconferences, chats, Wikis, blogs, web pages, etc., participating in collaborative learning processes by using several of them (University of Murcia, 2010). The Sakai platform was later replaced by the virtual classroom of the University of Murcia without losing the essence of the methodological strategies used.

The subject on which the research study is based is called ‘The educator as a cultural mediator. Strategies for social inclusion in museums’. This is an optional subject within the organisational structure of the Master's Degree in Education and Museums, but carries a load of 6 credits, as is the case with the compulsory subjects in the programme. It is taught for 21 days in the second term and the methodological proposal related to the object of the research involves: videoconferencing, forums, assignments and Wiki (Table 1).

Table 1
Methodology used in the subject

Tools	Activity/Description	Type
Videoconference	Introduction to the subject	Synchronous/Group
Forum	Student introductions	Asynchronous/Individual
Forum	Activity 1. Addressing theoretical knowledge. Socio-cultural facilitation	Asynchronous/Individual
Forum	Activity 2. Addressing theoretical knowledge. Proposals for museum action	Asynchronous/Individual
Assignment	Activity 3. Addressing theoretical knowledge. Search for programmes	Asynchronous/Individual
Forum	Activity 4. Addressing theoretical knowledge. Attitudes of the educator	Asynchronous/Individual
Wiki*	Activity 5. Addressing practical knowledge. Examples of socio-cultural facilitation strategies	Asynchronous/Group
Assignment	Activity 6. Addressing theoretical knowledge. The role of the museum educator	Asynchronous/Individual

Tools	Activity/Description	Type
Assignment*	Overall activity. Addressing practical knowledge. Museum intervention project	Asynchronous/Group
Assignment	Test of content covered in the subject	Synchronous/individual
Portfolio	Evaluation	Asynchronous/Individual
Forum	'Telegram' Students' general views on the subject	Asynchronous/Group

Source: Developed by the authors.
*Collaborative activities

The subject with which this article is concerned used collaborative learning strategies that included discussions and group work. Two collaborative activities were selected for the study: activity 5 and the overall activity. Activity 5 used the Wiki tool. It was used to develop a process focused on designing strategies for socio-cultural facilitation. The aim was to specify proposals for action in museums by adopting the perspective of the course; the activity involved the issue in question and its methodological approach, and was carried out in a group (8 students). The overall activity used 'the assignment tool (among 5 students). It consisted of creating a socio-cultural facilitation intervention project that met the need of helping a group at risk of social exclusion participate in the daily life of museums. The instruments used in the research were the outcomes of these collaborative activities included in the portfolios and the content of the 'Telegram' forum. In addition, students were asked to participate in a focus group session, as detailed in the relevant section.

Participants

The portfolios of the students who completed the course 'Museum Educator as a Cultural Mediator. Strategies of social inclusion in museums' over the last six academic years were consulted for the study (N=211). The gender composition of the study group was 14.2 % male and 85.8 % female. Regarding their previous education, 55.7 % of the students came from teaching professions, while 44.2 % came from multidisciplinary professions, a large number of them from the area of Geography and History, and some from Fine Arts, Library and Information Science, Psychology and Tourism. Of the three periods covered in the study, 43.0 % of the sample took the course before the onset of the pandemic (academic years 2017-2019); 39.2 % during the pandemic and de-escalation (academic years 2019-2021), and 34.2 % in the post-pandemic period (academic years 2021-2023). Despite the fact that this master's degree is for one year, it was decided to group the study into three biannual cohorts, in order to coincide with the terms established by the educational authorities as a result of the lockdown due to the pandemic and de-escalation. With regard to the marks obtained by students in the subject, 19.7 % had an 'A' grade, 66.8 % had a 'B' grade and 13.5 % had a pass.

Procedure and instruments used for data collection

The Virtual Classroom and a focus group were used to consult the digital archive related to the subject. Access was gained to the history for the last six academic years in order to collect the relevant data in the digital archive. This was where the students had uploaded the work they had submitted each academic year and also contained their grades. As noted above, three instruments were used to collect information about the students' views on the collaborative activities mentioned in connection with the research context:

1. Firstly, the e-portfolio (where students used the 'assignment' tool). The subject uses a development guide in line with the suggestions provided by García Sanz (2008) to evaluate learning. This guide required students to reflect individually about: (1) activities; (2) contents; (3) skills; (4) difficulties; (5) methodological assessment of their experience; (6) self-evaluation of metacognitive processes.
2. Secondly, the forum. The 'Telegram' (Froufe, 1998) qualitative technique was used to ask students to evaluate positive and negative elements of the subject on an individual basis and in an open narrative format. This allowed them to identify issues related to the methodology used, the design of activities, motivation and support among students. It was required to be between half a page and a full page in length.
3. Thirdly, a qualitative instrument, the focus group. Seven students representing all three bi-annual periods participated in order to inform the study, reflect on previously observed data and provide researchers with a better understanding of students' perceptions of and experiences in relation to the collaborative activities implemented in the subject. Initially, four main areas of interest were proposed: activities and tools proposed in the subject; interaction and communication between students; benefits of collaborative learning; and impact of the course on their professional work. The considerations laid out by Mayorga Fernández and Tójar Hurtado (2003) were followed to this effect.

Data analysis

Careful contemplation was used to gain a deep understanding of the data through the application of the reflective thematic analysis technique (Braun & Clarke, 2022; Terry & Hayfield, 2021), giving importance to the researchers' critical study of their decisions. It was also used in combination with constant comparison analysis (Leech & Onwuegbuzie, 2008), which involved recurrently comparing the data and making improvements to the analysis. These two methods were essentially chosen for their flexibility. In the method of analysis used in the study, a number of themes were sought by identifying patterns in the data, and these themes then gave rise to core categories and related categories. These categories are comparable to the codes and subcodes used in analysis software, as the methodological framework of analysis was modelled on key publications in the use of the software (Soratto et al., 2020).

The method of data analysis outlined (Braun & Clarke, 2022) was applied in a series of stages that were, in turn, sequential and recursive. This meant that the different phases could overlap, thanks to the reflective process inherent in the model used. These phases were as follows:

- A phase in which team members became familiarised with the data by engaging in analytical reading.
- A phase that involved generating a code book of categories, segmenting meaningful data to identify categories and subcategories, defining and exemplifying them. In this case, a balance was struck between data-driven analysis and theory-driven analysis (Braun & Clarke, 2012). Coding was carried out by the study's three authors, all of whom had previous experience and specific training in the area of qualitative research methodology. Meetings were held to discuss and reflect on the coding process until coding stability was achieved (Terry & Hayfield, 2021).
- A phase in which themes of interest were established by looking for categories to obtain patterns of relationships between data, using core categories in different clusters of related categories.
- A review phase of themes to check their quality by comparing them with the data obtained in order to confirm or reject core categories.
- A phase in which categories were given their final names, delimiting them and connecting them with others, generating definitions associated with salient quotations from the situation described that help to clarify the category.

The qualitative analysis was carried out using ATLAS.ti V22 (Scientific Software Development GmbH) because, according to Soratto et al. (2020), it allows for the easy visualisation of qualitative information of interest provided by the dynamics of comparison and contrast between the codes or categories assigned to the data.

Similarly, two dimensions were identified within the data analysis which would help to compare student contributions: (1) Students' academic year (2) Grades obtained.

RESULTS

Analysis of students' benefits from and difficulties with online tools and activities

The first and second objectives entailed examining the benefits and difficulties reported by students regarding tools and collaborative work. A preliminary finding was the book of categories from phase two of the analysis, which is outlined below. As there were no pre-established categories, these categories were the themes that emerged from the inductive analysis of the data, which guided the rest of the analytical phases. They were grouped into two main areas that refer to the use of collaborative tools, as well as to the processes involved in the activities themselves. The themes around which the students' discourse revolved were:

- Collaborative activities, used to refer to activities carried out by students collaboratively.
- Benefits (either from the activities or the methodology) as reported by students.
- Difficulties students faced while engaging in the activities or the course.
- Group dynamics, which refers to the different processes involved in working groups and internal group dynamics.

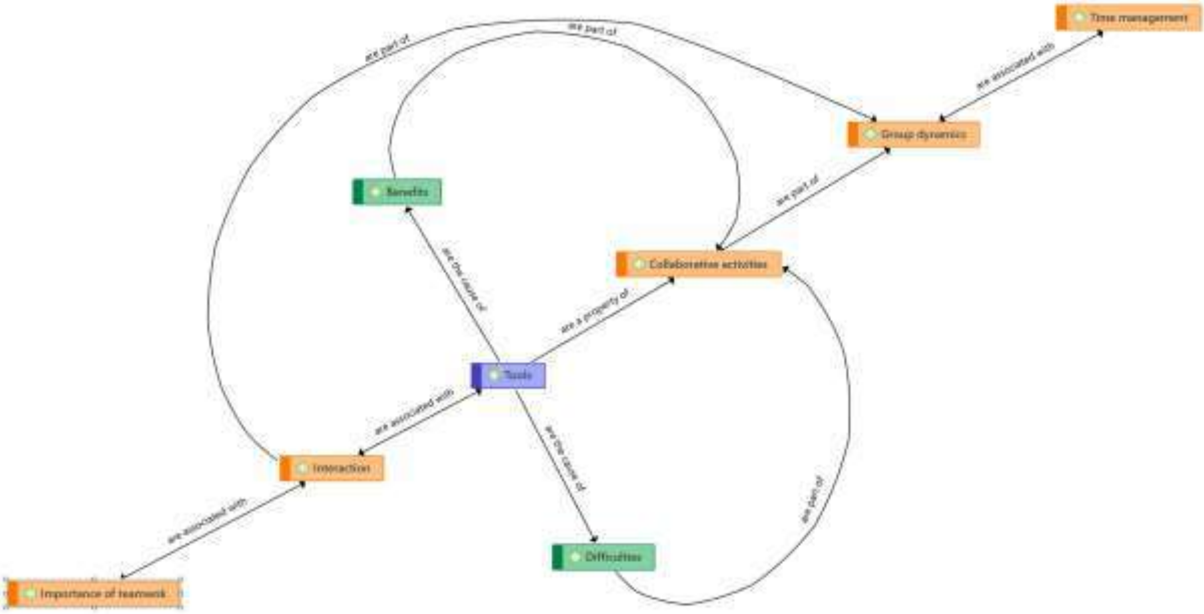
- Time management, when students mentioned the timing of activities.
- Tools, when participants mentioned the instruments used in the activities.
- Importance of teamwork, which indicates the specific quotations that pointed to the significance of working as part of a group and their reasons underlying their views.
- Interaction, when general aspects of the interaction either among students or between students and teaching staff were mentioned.

Once the data analysis had been carried out, several central categories emerged from these themes, which were the focus of the first two specific objectives set out in the research. In particular, the two central themes on which the students' discourse focused were the tools they used when completing the activities and the collaborative activities themselves. The two themes were closely intertwined, since the first theme (tools) was semantically circumscribed to collaborative activities. In other words, the tools mentioned were requirements for carrying out the activities, 'the activity will be carried out using a Wiki-forum, where the members of the group will pool their knowledge' (D136:9).[1]

Following the thematic analysis, a series of aspects related to the two central emerging categories were identified as being significantly associated with each other based on the co-occurrence coefficients provided by the analysis software.[2] In particular, these aspects associated with the main themes referred to two specific issues. On the one hand, the benefits and difficulties encountered by the students in their learning process and, on the other hand, the different group dynamics in the interactions that the participating learners engaged in. In fact, it is common to identify the reasons for the benefits and difficulties found in collaborative activities by examining these work dynamics.

The semantic network shown below was generated as a sample of the relationships that were established in the learning process (Figure 1). Firstly, the relationship between the tools used and the two collaborative activities mentioned in the portfolios. The use of these tools also presented different difficulties and benefits which were identified by the students. Some general benefits and difficulties of the activities and tools used were featured: 'the Wiki activity' was very rewarding (D9:1); 'I am referring to the Wiki assignment, which required two groups work together and organising it was much more demanding, [...] the group is quite large' (D117:10).

Figure 1
Semantic network of relationships between categories



An important group of students were not clear about the different tools to be used in their collaborative work, since the activity was mainly based on conceptual development using that tool, in this case, Wiki. In fact, the activity itself was largely defined as the development of this Wiki document, 'the creation of a cooperative document using Wiki, in which proposals were shared' (D3:1). By doing so, students were asked to create content and identify this outcome as an end-product of their learning, not as a means to learning. However, some of them stated that this work was part of the itinerary that leads to learning: 'the assignments played an essential part in understanding the contents of the subject [...] as in the case of Wiki and the overall activity' (D66:9).

They also mentioned other tools which were useful to them in carrying out the assignment in which they had to construct the overall activity. These include basic communication tools such as WhatsApp, and work tools such as Google Drive. These were used to complement their work due to the benefits they provided in contrast to those of the virtual classroom, such as facilitating collaborative work: 'this activity [...] is carried out through a platform outside the virtual classroom (Drive), as it allows us all to work and edit the same document and subsequently link the outcome to the virtual classroom assignments section'. (D115:19).

The space in which the assignment took place therefore had a significant impact on how the activity was carried out, the group dynamics and, consequently, on the learning process. The fact that the workspace facilitated these dynamics was highlighted in the discussion group, 'with Wiki you had to use the virtual classroom but in the end, the communication that WhatsApp allows you to have) you don't get from the virtual classroom' (GD.D144:25). This may lead to the expectation that shifting the activity and using tools outside the virtual classroom may be beneficial to the work. In this way, they were clear about the involvement of all their fellow students in the assignment. This is because 'on the Wiki platform it is often not clear how many classmates are participating in the preparation of a document' (D91:19); another student noted: 'I agree that the negative point in Wiki activities is working cooperatively, virtually, without the format allowing online editing. I think it gets in the way and requires doubling the work'. (D10:2)

Similarly, the focus group reinforced a related idea, namely, that the amount of time and the pace of work or dedication of their fellow students also affected their dynamics, 'in the end some of them decided to go their own way. No, it's not that we kicked them out of the group, but that they understood that they couldn't keep up with the others' (GD.D144:37). Thus, they indicated that group self-regulation was part of their dynamics and was of great importance for them, both in the process and in terms of producing the final outcome. However, this was seen as an advantage by other participants, since the differences that arose, for one reason or another, were compensated for by the group: 'I don't have any complaints at all, either about those who were my permanent work team members for all the subjects and in the Wiki [assignment], I think there was very much a mixed group, because there were two art historians, a curator, two teachers, then the girls in Wiki were teachers, and so [....] what I might have lacked in terms of technology skills, they made up for, and then I contributed other things' (GD.D144:49).

On a different note, it seems that the use of the platforms was not clear to some students. When talking about the assignment procedures there were contradictions within the same portfolio; sometimes they highlighted the tool and sometimes the modality. At other times they confused the tools or were not clear about their differentiation: 'this is the Wiki-forum activity' (D12:2). These were particularly remarkable issues, as they suggest that hyperconnectivity was a characteristic sign of the years covered in the study, even before the period of isolation.

This difference between the profiles of the students, their knowledge or lack of knowledge of the different tools, means that the learners engaged in many dynamics out of habit. The assignments completed in person in other studies and the collaborative activities in different contexts made a difference to them in terms of work progress, 'getting organised when carrying out the assignments, but this is normal in group work' (D143:25). In these kinds of activities, whether online or offline, it is always beneficial to observe different points of view, for example: 'the Wiki activity is always suitable for joint learning, the problems were solved within the group and that is also a positive aspect. Especially doing cooperative work, exchanging views, ideas, choosing the resources that we thought would be the most useful...' (D7:6).

Likewise, although difficulties such as those mentioned above may arise, this kind of work always needs a positive, supportive dynamic where students find a space to share their concerns. This is often motivated by the collaborative nature of the activities, 'as well as creating bonds with the members of another group, we were also able to "see beyond" our own perception' (D18:1); 'the work was an essential part of understanding the content, the difficulty of which varied, and where group cohesion was necessary, as in the case of the Wiki or the overall activity' (D66:9). The need for interaction between students was echoed in the focus group discussion. The students indicated that these assignments required first building a relationship between group members, which needs to be gradually developed: 'we have not had contact before, in most cases it makes group work less fluid' (GD.D144:25).

Although the course was a virtual learning programme, there was a clear need for connection between participants. Thus, the tools, as well as being the means to carry out the activities, greatly influenced the different activities and the difficulties that may be encountered: 'above all, ensuring that all the members in the group were equally involved' (D143:12). However, this does not entail that the use of the tools was not aimed at improving their work dynamics, 'the Wiki activities were beneficial and brought positive aspects' (D143:40).

Comparative experience of students

In order to address the third specific objective of the study and describe the comparative experience of the tools' use by the participating students, the grades obtained by the students were recorded, and whether they had engaged in the postgraduate programme before, during or after the pandemic. Table 2 shows the impact of the two central categories in terms of students' grades. It can be seen that the percentage difference between them was not significant in any of the cases. This indicates that, the different collaborative activities the students performed online and the tools used for them were mentioned equally, regardless of the different grades that students were awarded.

Table 2

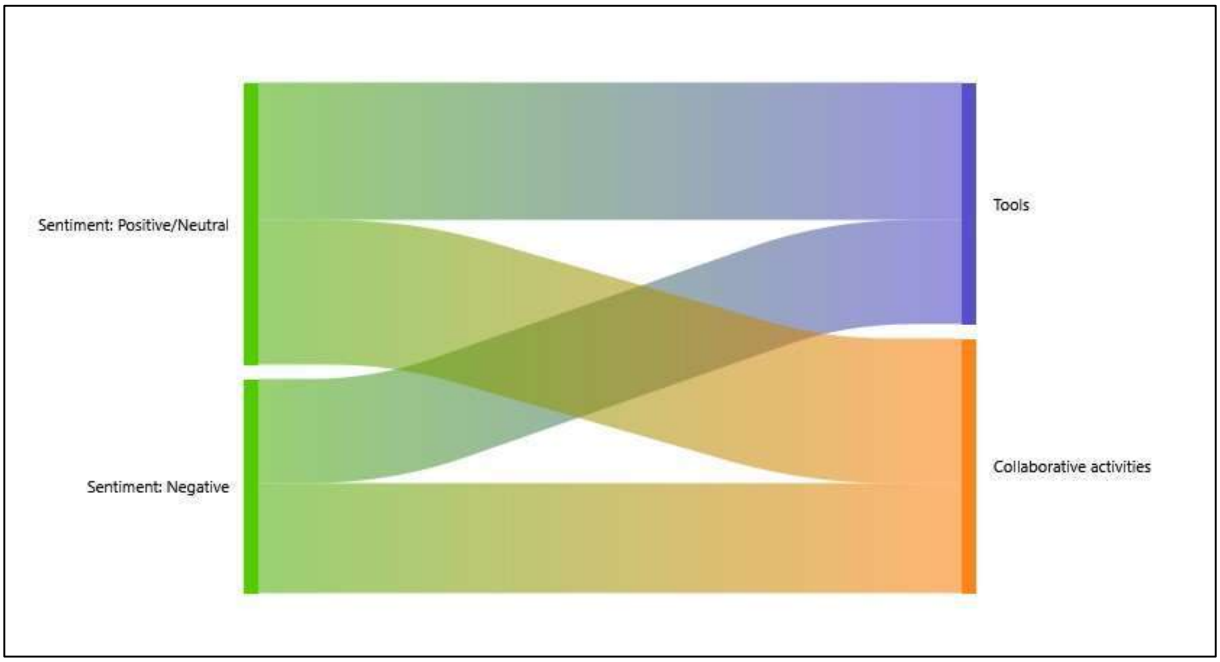
Category-document table between core categories and student grades

	GRADES		
	Pass	**B**	**A**
Collaborative activities	33.61 %	34.46 %	31.93 %
Tools	33.02 %	32.09 %	34.88 %

Looking closer at the students' perceptions using the sentiment analysis provided by the analysis software, as shown in Figure 2, there was a higher positive/neutral sentiment towards both the tools and the collaborative activities. There was also an even distribution of sentiment between each of the categories. If filters were applied in the programme according to their grades (not reflected in figures or tables for the sake of image economy), the students with a pass grade had greater affinity for the tools, but not for the collaborative activities. In contrast, students awarded As and Bs expressed a more positive/neutral feeling for collaborative activities to the detriment of the tools.

Figure 2

Sankey diagram of the relationship between core categories and student sentiment



If the same table is considered by looking at the different the periods, that is, before, during and after the COVID pandemic (Table 3), some values stand out from the others. It was found that collaborative activities had a higher impact during and after the pandemic than before, which suggests that it was not an important issue in period preceding the lockdown stages. In contrast, the tools used had a greater presence in the stage prior to COVID than in the periods that followed it. It could be inferred from this that before the pandemic the tools were more of a novelty to the respondents, which is why they emphasised their use. However, after a period in their lives when their learning took place using these tools, they became normalised and they were no longer noteworthy.

Table 3

Category-document table between core categories and periods studied

	Pre-COVID period	**During COVID**	**Post-COVID period**
Collaborative activities	27.64 %	36.17 %	36.18 %
Tools	39.28 %	30.36 %	30.35 %

It is worth mentioning that there were variations in the perceptions and assessments the participants made in this respect. In the pre-pandemic context, greater concern was identified in relation to peer support and group work. On the other hand, views expressed by the students about the teaching process, the technical support provided and the motivation of the teaching staff were very positive. During the lockdown period, they held a critical view of the internal dynamics of group work, although their comments showed a marked improvement in the perception of peer support. Again, the teaching process, tutoring and technical support, and the motivation of the teaching staff were held in high regard. In the post-pandemic period, ratings regarding group work decreased in terms of effectiveness, while ratings of the teaching process, tutoring, technical support and teacher motivation increased.

DISCUSSION AND CONCLUSIONS

The aim of this research was to gain further insight into how graduate students from different disciplines constructed knowledge and established relationships in formal, non-face-to-face educational environments using collaborative activities. Specifically, an optional subject of the Master's Degree in Education and Museums was chosen due to its practical and applied nature. To this end, the general objective was broken down into three major areas: to analyse the benefits and difficulties encountered by postgraduate students regarding the tools used in online collaborative methodological processes, as well as in the collaborative activities in which these tools were employed, and whether the pandemic was a factor in terms of the processes experienced before and after the lockdown stages, including its relationship, if any, with the grades obtained by the students.

With regard to the first objective, the results indicate some disparity in the students' responses regarding their grasp or conceptual knowledge of the tools. In fact, a detailed analysis of the information shows that questions relating to knowledge of the tools are under-represented. Much more emphasis was placed on the processes concerning the activities performed. On the other hand, the participants knew how to handle them, although they found it difficult to differentiate them from the activity itself when it comes to defining them. The usefulness of the tools and their role in the teamwork dynamics and facilitating collaborative work is also noteworthy. This finding is consistent with previous research on systematic reviews of collaborative learning tools such as that by Valencia and Rodríguez (2019). In relation to the second objective referring to the benefits and difficulties encountered while performing the activities analysed, the results could be synthesised into three perspectives: the positive aspects highlighted by the participants, the needs that require this type of methodological approach, and the proposals for improvement.

Firstly, the benefits of their use include personal and academic satisfaction. They also refer to the opportunities for building interpersonal relationships and engaging in communication between learners. These data are in line with those obtained in the study by Tusyanah et al. (2023) when they referred to the increase in cognitive performance as well as critical thinking skills. Furthermore, the results point to the possibility of building an interdependent and inclusive learning experience. These results could be encompassed in what Rodríguez Marconi et al. (2023) called transversal competences.

Secondly, in terms of the needs identified, the importance of the group's maturity to operate in this type of collective experience should be emphasised. The order in which the subjects are taken is relevant to the research presented. The fact that this is one of the last subjects completed within the Master's Degree programme provides momentum for the use of collaborative methodology. However, this variable was not identified in the study by Palacios et al. (2022), who reported other variables related to effectiveness including empathy, the feeling of mutual help, and the management of assertiveness. The need for the group to self-regulate was highlighted, similarly to how

Niño and Castellanos (2020) did when they discussed shared regulation in all stages of the activities.

There were also some ecological issues to be emphasised in connection with the findings, such as the temporal dimension pointed out by Barrera et al. (2021), particularly identifying significant differences in the timing of student contributions. However, neither the design nor the data obtained in this study allow this to be stated unequivocally. There was a wide range of levels in the digital skills of postgraduate students when preparing their portfolios. This is a factor that was highlighted in the study conducted by Marcano (2023) for digital skill training of teaching staff, which should also be taken into account in order to make the design of teaching tools more flexible. Perhaps the use of tools such as Wiki should return to their essence as a means of teaching. This would involve reinforcing not only the completion of the final assignment, but above all, self-learning processes. According to De Arriba and García (2014) and García Chitiva (2020), it is necessary to enhance metacognitive psychological processes. However, in order to achieve the appropriate use of collaborative methodological strategies, the students who participated in this study reported some elements that needed to be improved, in line with Aguilera (2023). For example, equal time spent by students and monitoring of performance; greater demands regarding the management of the group size than individual activities; and improving the tool itself to detect the actual involvement of each member of the group.

In connection with the third objective of the study, some changes were suggested in the perception and use of collaborative activities and tools before, during and after the pandemic. Students' attention to collaborative processes during the pandemic was high in terms of valuing and enriching peer-to-peer contributions compared to other periods. This could indicate an adaptation to the harsh circumstances perceived by the learners during the lockdown period in terms of socio-emotional and affective impact, as well as to the various functions of social media and social technology for learning during lockdown, which were pointed out by Piki's (2022) study, where collaboration became relevant. It is also worth noting that the prevailing references to issues related to educational tools initially found in participants' comments declined in the later stage. This suggests that these tools were previously seen as novel in contrast to the familiarity with which they are now perceived. This may indicate an emphasis on collaboration and interaction between learners, rather than on specific tools.

The main limitation of the study is that it would have been beneficial to have gone further into the educational processes without interruptions; however, the pandemic prevented this. Although this Master's degree was delivered online, the students were affected by the situation they experienced, which meant that they were unable to engage in the programme as a continuous process. This circumstance was used by the research group itself to make the decision on the approach and design, and the opportunity was used to consider it as a differential aspect.

With regard to the socio-educational and didactic implications that could be derived from the study, it raises a fundamental question that deserves reflection, namely, how students will approach collaboration and technology in the future. The integration of tools and the modification of platforms to adapt them to the current needs of learners is a key issue. It was perceived, both in devising the theoretical framework and in the data collection and analysis, that students express an interest in having the tools adapted to ensure that they relate to their everyday digital experience. Therefore, a contribution of this study is that a need has been identified for pedagogical designs to promote enhanced technical skills in the use of digital tools through a reflexive and critical approach. Our findings also highlighted the importance of fostering a focus on collaborative competences in the online postgraduate course, where students can acquire inter-group communication and problem-solving skills in multidisciplinary professional teams. Furthermore, the retrospective methodological design and the qualitative analysis employed can serve as a starting point for future research.

NOTES

1. The different fragments extracted from the data were referenced by the analysis software used, where the document number is shown preceded by a 'd' and the quotation number within that document. In addition, the data extracted from the focus group was marked with the acronym GD (by its initials in Spanish).
2. Co-occurrence coefficients were provided by the categories that co-occurred in the same quotation. The higher the co-occurrence of codes in different quotations, the higher the coefficient. More information can be found at: https://doc.atlasti.com/ManualWin/CodeCooccurrence/CodeCoOccurrenceTools.html

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Creation and validation of a technopedagogical design with flipped learning and collaborative writing

Creación y validación de un diseño tecnopedagógico con aprendizaje invertido y escritura colaborativa

Gilber Chura-Quispe - *Escuela de Posgrado Newman (Peru)*
Raúl Alberto García Castro - *Universidad Nacional Jorge Basadre Grohmann (Peru)*
Gladys Pilar Limache Arocutipa - *Universidad Nacional Jorge Basadre Grohmann (Peru)*
Bianca Daisa Laura De La Cruz - *Escuela de Posgrado Newman (Peru)*

ABSTRACT

Academic writing is a complex transversal competence that still represents a challenge for the development of university education. This challenge involves improving the capacity for argumentation, organization of ideas, and linguistic skills through the implementation of appropriate practices in didactic processes. The objective of this research is to create and validate a technopedagogical design with flipped learning and collaborative writing (TPD-FLCW) to enhance the production of academic texts. The research was conducted with Peruvian university engineering students (diagnostic stage = 89 and experimental stage = 40) and 16 expert professors. The ADDIE model with five phases was used: analysis, design, development, implementation, and evaluation. The initial diagnosis revealed that students had difficulties in academic writing. Based on these results, the proposal was designed and validated with the participation of judges ($CVC > 0.9$; $K_{Fleiss} > 0.3$, $p < 0.05$). The application in the experimental group showed significant improvements in the essays produced before and after the intervention ($p < 0.05$; $\hat{g} > 1.20$). Additionally, the students' assessment was positive, and they reported having improved their writing skills, autonomy, and teamwork capacity. It is concluded that the TPD-FLCW proves to be effective and adequate for learning academic writing, and its use is recommended for learning other types of texts.

Keywords: learning strategies; flipped learning; collaborative writing; technopedagogical design; validity.

RESUMEN

La escritura académica es una competencia transversal compleja que aún representa un desafío en el desarrollo de la formación universitaria. Este reto implica mejorar la capacidad de argumentación, organización de ideas y habilidades lingüísticas mediante la implementación de prácticas apropiadas en los procesos didácticos. El objetivo de este trabajo es crear y validar un diseño tecnopedagógico con aprendizaje invertido y escritura colaborativa (DTP-AIEC) para mejorar la producción de textos académicos. La investigación se realizó con estudiantes universitarios peruanos de ingeniería (etapa diagnóstica = 89 y etapa experimental = 40) y con 16 docentes expertos. Se empleó el modelo ADDIE con cinco fases: análisis, diseño, desarrollo, implementación y evaluación. El diagnóstico inicial evidenció que los estudiantes presentaban dificultades en la escritura académica. Con base en estos resultados, se diseñó y validó la propuesta con la participación de jueces ($CVC > 0.9$; $K_{Fleiss} > 0.3$, $p < 0.05$). La aplicación en el grupo experimental evidenció mejoras significativas en los ensayos producidos antes y después de la intervención ($p < 0.05$; $\hat{g} > 1.20$). Además, la valoración de los estudiantes fue positiva y manifestaron haber mejorado sus habilidades de escritura, autonomía y capacidad de trabajo en equipo. Se concluye que el DTP-AIEC demuestra ser eficaz y adecuado para el aprendizaje de la escritura académica y se recomienda su empleo para el aprendizaje de otros tipos de textos.

Palabras clave: estrategias de aprendizaje; aprendizaje invertido; escritura colaborativa; diseño tecnopedagógico; validez.

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INTRODUCTION

Current education is strongly influenced by socio-constructivism (Da Fonseca et al., 2021). This theory assumes that the understanding, meaning, and significance of learning develop in the interaction between people (Amineh & Asl, 2015). Learning occurs first at the social level and then individually (Vygotsky, 1978). In 21st-century pedagogy, collaborative learning is a practical response to the theoretical approaches of socio-constructivism. Collaborative learning is defined as the teamwork of two or more people working towards the same goal with a common and symmetrical commitment (Jeong & Hmelo-Silver, 2016). In addition, collaboration among members fosters critical thinking and active participation, enhances learning, and models various techniques for solving problem situations (Laal & Ghodsi, 2012).

Writing competence is transversal in nature and is associated with the achievement of generic competencies within the curricular structure (Barreda-Parra et al., 2023). However, the difficulties lie at the beginning of professional training and are associated with paraphrasing (Tan & Carnegie, 2022), recognition of authorship in citations and references (Acosta et al., 2023), use of language, organization of the text, writing processes (Direkci et al., 2022), and adoption of inappropriate practices such as plagiarism (Festas et al., 2023). This is further compounded by the existence of implicit theories that make writing practice invisible; for instance, assuming it as a mere act of transcription, talent, inspiration, basic skill, lexis, or spelling and not as an object of teaching (Navarro & Mora-Aguirre, 2019) may end up diverting its practical exercise.

Given this situation, various strategies have been implemented to improve academic writing competence (Andueza-Correa, 2022; Yuliani et al., 2023). Successful experiences in recent years have highlighted collaborative learning as the strategy that has the most significant impact (Sundari & Febriyanti, 2023; Zou et al., 2022). Collaborative learning and online education are the new challenges in subjects that require hands-on development (Roxas, 2023), where interaction between peers and teachers is indispensable. Collaborative writing begins with brainstorming during text planning (Svenlin & Jusslin, 2023) and culminates in revising drafts of the writing before final submission (Thirakunkovit & Boonyaprakob, 2022).

The use of collaborative writing (CW) is becoming increasingly common in the development of writing competence (Fanguy & Costley, 2021). In pedagogical settings, teachers have started to incorporate it in the presentation of final-year work (Pham, 2023). However, they spend most of their class time on content presentation (Palau & Fornons, 2022), which leads to the technique being applied outside of class (asynchronously) to accomplish the assigned task, rather than as a didactic strategy during the session (Hsu, 2020). Although empirical evidence for writing development has been relatively successful in addressing the achievement of writing proficiency, there are still methodological difficulties in the role of students and teachers (Zhang et al., 2021).

An active methodology such as Flipped Learning (FL) applied by teachers to the teaching of writing would optimize the time devoted to the development of higher-order thinking and competencies (Sargent & Casey, 2020). FL involves modifying the order of the teaching-learning processes: at home, learning is mainly individual with the use of various study techniques such as videos, texts, audios, among others;

whereas, in the classroom, students apply that theoretical knowledge (Santiago & Bergmann, 2018). Research in the field of writing has empirically investigated the benefits of FL at cognitive, procedural, and emotional levels (Ebron & Mabuan, 2021; Özdemİr & Açik, 2019). The acquisition of content knowledge is matched to students' learning paces, more class time is devoted to workshop execution, and there is greater confidence in hands-on activities due to teacher supervision (Owen & Dunham, 2015).

Technopedagogical design for academic writing

The combination of technology, content, and pedagogy (Koehler et al., 2015) shapes a scenario in which technopedagogy is of crucial importance in today's education. From this perspective, the teacher assumes the role of technopedagogue to provide solutions to educational problems, such as the development of writing skills. However, he/she must first have developed technopedagogical competencies to plan, implement and evaluate educational processes (Niess, 2005). Hence, the use of software, simulations, platform navigation, among other resources, is imperative.

Current writing demands the mastery of various resources, such as search engines, text editing tools, reference management, style correction, plagiarism detection, etc. (Martínez-López et al., 2019). These resources are used in educational practice through activities that direct the interactive triangle (teacher, student, and content), giving rise to the technopedagogical design (Hernández & Muñoz, 2012). This design involves the integrated exploration of the contributions of digital technology in the teaching and learning processes of academic writing (Shanks & Young, 2019). It requires systematic and rigorous planning of the activities and procedures that the teacher will apply to ensure that students acquire learning efficiently, making use of methods or techniques and digital or technological resources.

Flipped Learning and Collaborative Writing

FL is a model rooted in constructivist pedagogical theories, positing that the construction of students' learning is attributed to their cognitive ability to comprehend the material or course content (Lindeiner-Stráský et al., 2022). In FL, students engage in various activities before the start of class with the aim of acquiring content knowledge to then apply that knowledge during in-person sessions. (Santiago & Bergmann, 2018). In addition to improving writing proficiency (Zhao & Yang, 2023), FL promotes autonomy, motivation, metacognition, adaptation to learning pace, ease of feedback, and engagement (Huang et al., 2023; Thai et al., 2023).

Parallelly, CW is presented as an effective strategy to carry out the writing processes. This activity implies that co-authors (students) actively participate in all phases of writing, assuming a responsible commitment and ownership of the final document (Storch, 2019). CW is grounded in theories such as socio-constructivism (Vygotsky, 1978), group cognition (Stahl, 2004), and connected learning (Ito et al., 2013). Its didactic application demands the use of collaborative digital tools, such as blogs, wikis, interaction rooms, academic forums, or more up-to-date tools such as Google Docs (Suwantarathip & Wichadee, 2014).

The interest in proposing an enhancement in the production of academic texts by university students leads to the objective of developing a technopedagogical design that integrates Flipped Learning and Collaborative Writing in virtual educational settings, with the subsequent aim of validation. The proposal encompasses five phases in the process.

METHODOLOGY

Method

In the study, qualitative and quantitative techniques are employed, because the creation and validation process unfolded in five phases following the ADDIE model: analysis, design, development, implementation, and evaluation (Kurt, 2018). Phase 1, "analysis", involves conducting a student diagnosis to identify the content to be developed and the needs of the educational context. In phase 2, "design", the syllabus of the course is developed, maintaining a pedagogical focus, the approach to the proposal, and the organization of content. Phase 3, "development", involves the selection, organization, and creation of content and materials used for learning based on the previously elaborated design. Phase 4, "implementation", focuses on the practical execution of the training action during the teaching and learning process of the students. Phase 5, "evaluation", represents the evaluative process of the previous stages and assesses the relevance of the proposal. The actions implemented in each phase are described below:

Phase 1 "Analysis": Firstly, the academic writing situation was diagnosed in three groups of students belonging to the Communication I course in the 2022-I term. The students composed a short argumentative text, with a length between 700 and 1000 words over a period of 8 hours asynchronously, addressing the question "What is the main contribution of the engineering field you study?" Subsequently, the generated products were reviewed to identify the issues. Secondly, the literature was reviewed, exploring the intervention of flipped learning and collaborative writing in the WOS and Scopus databases. Thirdly, the main theories of technopedagogical design were identified.

Phase 2 "Design": Fourthly, the technopedagogical design with Flipped Learning and Collaborative Writing (TPD-FLCW) was developed. The moments of each learning session (beginning, development, and closure) were taken into account, to which new designations were assigned (pre-phase, execution, and exit).

Phase 3 "Development": Fifthly, topics were selected and organized for the didactic guide through 9 learning sessions. Sixthly, didactic resources were developed in different formats (text, slides, audiovisual material). Seventhly, content validation was carried out with the participation of 16 expert judges in the field of university higher education. These judges were selected considering the following requirements: holding a doctoral degree, having at least 5 years of experience, being active in practice, and possessing experience in scientific research and writing. They evaluated the TPD-FLCW using the "Content Validity Protocol" instrument, based on 13 criteria on a Likert scale from 1 to 5, where 1 = inadequate, 2 = slightly adequate, 3 = moderately adequate, 4 = substantially adequate, and 5 = completely adequate.

Phase 4 "Implementation": Eighthly, the pre-assessment was applied; subsequently, after the intervention of the 9 sessions, the post-assessment was carried out on an experimental (pilot) group of university students enrolled in the Communication II course in the 2022-II term.

Phase 5 "Evaluation": Ninthly, all students who participated in the experiment were surveyed to obtain their appreciation regarding the model. Tenthly, 7 randomly selected students belonging to different workgroups were interviewed to understand their experiences during the sessions.

Participants

In the diagnostic phase, 89 engineering students participated: 35 in civil engineering, 19 in systems engineering, 13 in environmental engineering, 15 in industrial engineering, and 7 in electronic engineering. Among these, 55 were males (48.95%) and 34 were females (30.26%), with an average age of X=18.74 and SD=3.54. These students are enrolled in the Communication I course, corresponding to the first cycle of their degree program. In the validation phase, 16 expert judges with doctoral degrees, expertise in writing, and experience in university teaching participated. In both the implementation and evaluation phases, 40 university students from civil engineering (28), systems engineering (3), environmental engineering (6), industrial engineering (1), and electronic engineering (2) programs participated, enrolled in the second cycle of the Communication II course. Among this group, 13 were females (32.50 %) and 27 were males (67.50 %), with an average age of 18.53 and a standard deviation of 2.65. In the interviews, seven students randomly selected from different work teams of the experimental group participated.

Instruments

1. For the initial diagnosis of writing competence, an "Assessment Scale for Written Production" was applied, consisting of 10 criteria distributed across 3 aspects: structure, text property, and linguistic register. The scale (from 1 to 4) evaluates a brief argumentative text of 500 to 800 words.
2. To evaluate the TPD-FLCW, the "Pedagogical Proposal Validation Form" was utilized. The instrument comprises 13 evaluation criteria (relevance, justification, foundation, coherence, structuring, sufficiency, methodology, resources, updating, linguistic aspects, academic format, evaluability, and viability) on a Likert scale (1 = inadequate, 2 = slightly adequate, 3 = moderately adequate, 4 = substantially adequate, and 5 = completely adequate).
3. The academic essays were evaluated using an "Academic Essay Evaluation Rubric". The instrument presents 14 indicators assessing textual superstructure (title, introduction, written argumentation, written counter-argumentation, conclusion, references), textual macrostructure (coherence and thematic progression), textual microstructure (lexical relationships, references, and discourse markers), and stylistics (lexicon, spelling, and syntax) (Van Dijk, 1992). The descriptors include a scale ranging from poor (1) to excellent (4). It has an adequate content validity index (V_{Aiken}= 0.926) determined by 12 expert judges. Construct validity was measured with the participation of 117 academic essays written by university students and evaluated by 4 teachers. Exploratory Factor Analysis (EFA) identified adequate indices with an explained variance of 93.735

% (Bartlett < 0.05, KMO > 0.5), and Confirmatory Factor Analysis (CFA) with relevant adjustments in GFI, CFI, TLI (> 0.9), RMSEA (≤ 0.08) and factor weights > 0.5. The Composite Reliability Index (CRI > 0.9) was adequate.

4. A "Proposal Assessment Questionnaire" composed of 10 items with a 5-level Likert scale, ranging from (1) completely disagree to (5) completely agree, was used. The items assess students' perception of participation, peer learning, ease of writing, use of collaborative tools, argumentative improvement, time management, proofreading skills, intergroup revision, advanced information, and recommendation.
5. Additionally, a "Semi-structured Interview Guide" was applied as a control strategy to verify students' feelings about the functioning of the TPD-FLCW. The guide consists of 11 open-ended questions organized to explore three aspects: writing skills before the TPD-FLCW (3 questions), after the intervention of the TPD-FLCW (5 questions), and the difference between both (3 questions).

Procedures and information analysis

The qualitative analysis involved a literature review and interpretation of the interviews. The results were processed using grounded theory to analyze the interviewees' responses. On the other hand, the quantitative part comprised the evaluation of the diagnosis, experimental assessment, and questionnaire results with descriptive and inferential statistics. To assess agreement among judges, the Content Validity Coefficient (CVC) by Hernández-Nieto (Pedrosa et al., 2014) was employed. The results of the experiment were analyzed using the Student's t-test for paired samples (the data met the assumption of normality and homoscedasticity). Data processing and analysis were conducted using the R Studio program.

RESULTS

This section shows the different phases of elaboration and validation of the Technopedagogical Design with Flipped Learning and Collaborative Writing based on the ADDIE model. In each phase, the results found are described.

1. Analysis phase

a) *Diagnosis*

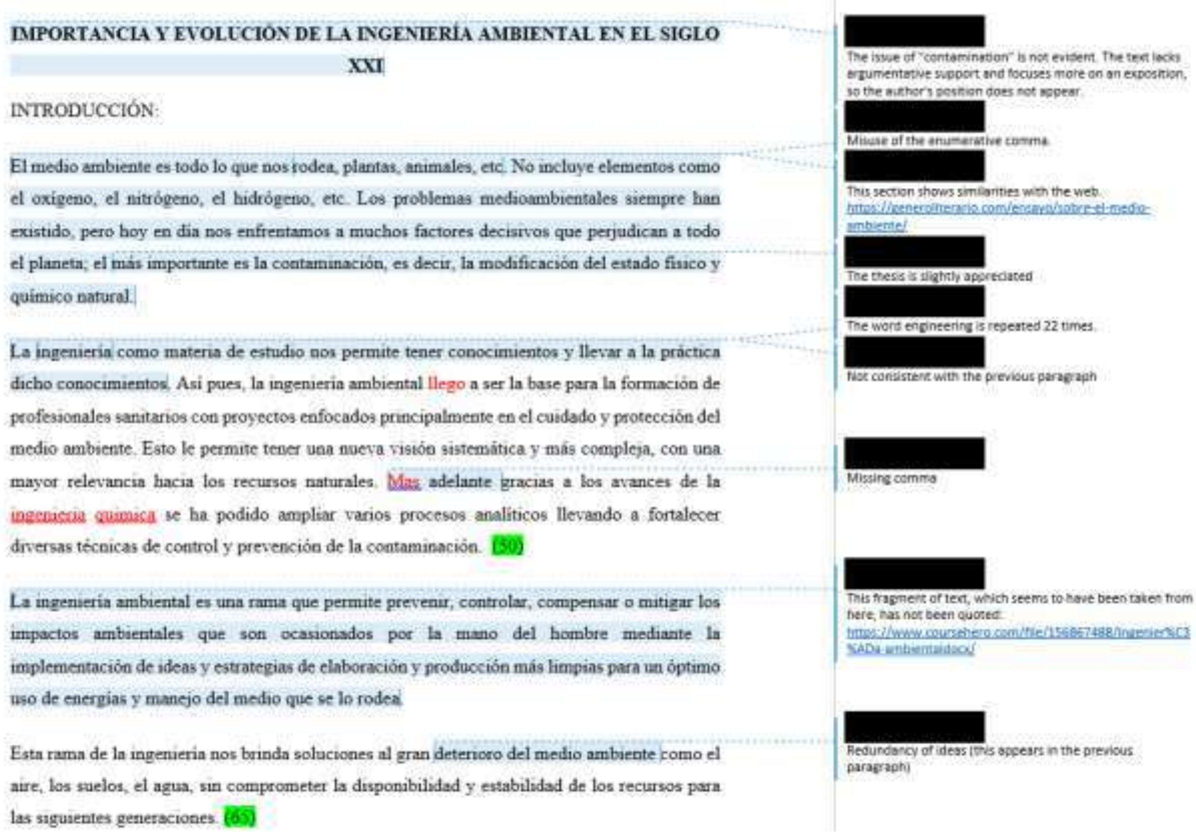
The results allowed us to identify that over 60% of the students present difficulties with the structure of their texts (introduction, development, and conclusion), properties (coherence and cohesion), and linguistic register (lexis, syntax, and spelling). Around one-tenth achieved a rating of good in each criterion (Table 1).

Table 1
Diagnostic assessment of students' writing situation

Criteria	Deficient		Enough		Well		Total	
	f	%	f	%	f	%	f	%
Structure	55	61.80	25	28.09	9	10.11	89	100.00
Text property	57	64.04	25	28.09	7	7.87	89	100.00
Linguistic register	61	68.54	20	22.47	8	8.99	89	100.00

The main needs for attention were identified in the lack of structural knowledge of an argumentative text, lack of coherence between statements, redundancy of ideas, little or no use of citations and references, problems with the thesis statement, poor argumentation, and confusion with the writing of expository texts. Some issues correspond to a lack of ethical conduct, as situations of copy-pasting information stored on the web were observed (Figure 1).

Figure 1
Fragment of an argumentative text presented by a student in a diagnostic assessment



IMPORTANCIA Y EVOLUCIÓN DE LA INGENIERÍA AMBIENTAL EN EL SIGLO XXI

INTRODUCCIÓN:

El medio ambiente es todo lo que nos rodea, plantas, animales, etc. No incluye elementos como el oxígeno, el nitrógeno, el hidrógeno, etc. Los problemas medioambientales siempre han existido, pero hoy en día nos enfrentamos a muchos factores decisivos que perjudican a todo el planeta; el más importante es la contaminación, es decir, la modificación del estado físico y químico natural.

La ingeniería como materia de estudio nos permite tener conocimientos y llevar a la práctica dicho conocimientos. Así pues, la ingeniería ambiental llego a ser la base para la formación de profesionales sanitarios con proyectos enfocados principalmente en el cuidado y protección del medio ambiente. Esto le permite tener una nueva visión sistemática y más compleja, con una mayor relevancia hacia los recursos naturales. Mas adelante gracias a los avances de la ingenieria quimica se ha podido ampliar varios procesos analíticos llevando a fortalecer diversas técnicas de control y prevención de la contaminación. (50)

La ingeniería ambiental es una rama que permite prevenir, controlar, compensar o mitigar los impactos ambientales que son ocasionados por la mano del hombre mediante la implementación de ideas y estrategias de elaboración y producción más limpias para un óptimo uso de energías y manejo del medio que se lo rodea.

Esta rama de la ingeniería nos brinda soluciones al gran deterioro del medio ambiente como el aire, los suelos, el agua, sin comprometer la disponibilidad y estabilidad de los recursos para las siguientes generaciones. (65)

[redacted]
The issue of "contamination" is not evident. The text lacks argumentative support and focuses more on an exposition, so the author's position does not appear.

[redacted]
Misuse of the enumerative comma.

[redacted]
This section shows similarities with the web. https://generoliterario.com/ensayo/sobre-el-medio-ambiente/

[redacted]
The thesis is slightly appreciated

[redacted]
The word engineering is repeated 22 times.

[redacted]
Not consistent with the previous paragraph

[redacted]
Missing comma

[redacted]
This fragment of text, which seems to have been taken from here, has not been quoted: https://www.coursehero.com/file/156867488/ingenier%C3%ADa-ambientaldocx/

[redacted]
Redundancy of ideas (this appears in the previous paragraph)

b) *Literature review*

Based on the results of the previous diagnosis, the literature was reviewed in the Scopus and Web of Science databases and two models were found to have a high impact on academic writing: Flipped Learning and Collaborative Writing. Significant changes in the production of different texts after the implementation of these models in the learning sessions are due to the use of technological support, active student participation, and teacher monitoring. The different experiments ranged in duration from 6 to 11 sessions with samples ranging from 24 to 113 university students (Table 2).

Table 2
Review of models for technopedagogical design

Model	Definition	Successful experiences	Authors
Flipped Learning	Instructional learning takes place at home through videos, lectures, or podcasts. Whereas in the classroom, more space is given to dynamic and interactive learning, where concepts are applied creatively in the course (Bergmann & Sams, 2012).	Paragraph improvement, argumentative essays, self-perception of academic writing	(Chura-Quispe et al., 2022; Khojasteh et al., 2021; Umutlu & Akpinar, 2020)
Collaborative Writing	It is an iterative and social process that requires the involvement of a collaborative team throughout all stages while engaging in activities such as communication, negotiation, coordination, supervision, socialization, among other activities (Lowry et al., 2004).	Improvement of review articles, essays, scientific articles, expository texts	(Baldwin et al., 2019; Roohani & Rad, 2022; Shafiee Rad et al., 2022; Zou et al., 2022)

c) *Identification of the main theories*

After reviewing the models that underpin the TPD-FLCW, the main theories that provide pedagogical support for the proposal were identified (Table 3).

Table 3
Main theories of the TPD-FLCW

Theory	Author	Theoretical framework
Theory of social-constructivism	(Vygotsky, 1978)	Cognitive development is first social and then individual. knowledge lies in the interactions between individuals.
Constructionism	(Papert & Harel, 1991)	It assumes the existence of skills for learning through experience and the ability to build a mental structure that organizes and synthesizes information and experiences. The student designs projects and is assisted by the computer.
Group cognition	(Stahl, 2004)	Learning is based on the exchange of strategies and a shared vision for problem-solving.

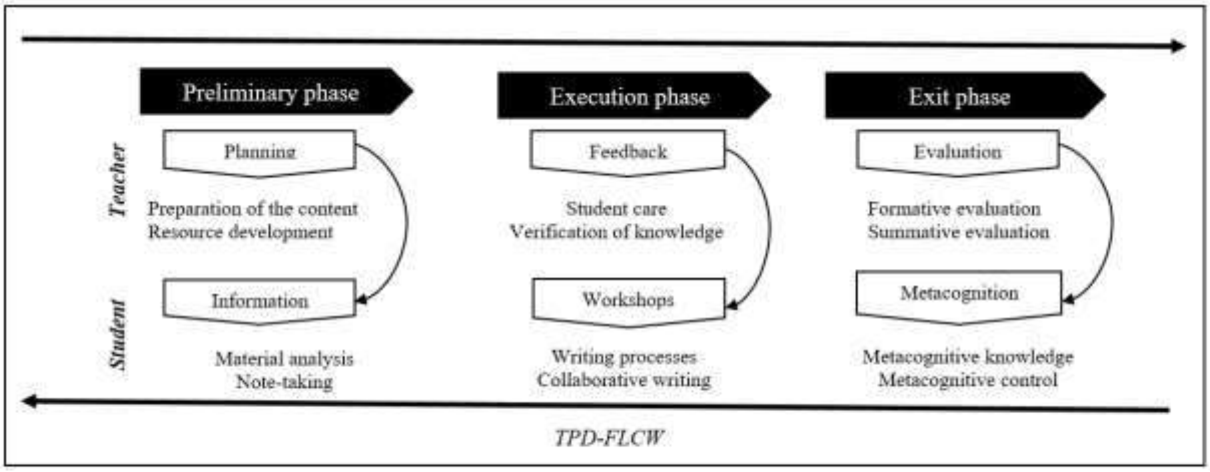
Theory	Author	Theoretical framework
Connectivism	(Siemens & Fonseca, 2007)	Learning takes place in changing scenarios (virtual environments and networking). It resides outside the individual and in the diversity of opinions. The student learns to choose information and the teacher guides him/her to discern it.
Connected learning	(Ito et al., 2013)	It encompasses learning according to students' interests and their relationship with others. It focuses on the abundance of information and connection through digital communication media.

2. Design phase

After exploring the main needs underlying students' academic writing, the TPD-FLCW was developed with three phases applied to each learning session (Figure 2): pre-phase, execution phase, and exit phase, representing continuous and cyclical activities (represented by arrows in both directions).

Figure 2

Technopedagogical Design with Flipped Learning and Collaborative Writing



Source: Chura-Quispe & Garcia Castro (2024).

a) *Preliminary phase of the TPD-FLCW*

It is the moment preceding the classroom session and occurs within the home environment.

(1) Planning. The teacher prepares the class content using updated sources and develops didactic resources in various formats (text, audio, video, images, etc.). While video is the most commonly used format, it is complemented by other resources. He/she also creates tools to guide students in acquiring theoretical content, such as questionnaires, prompts, reading guides, etc.

(2) Information. This is the stage in which the student analyses the digital resources provided by the teacher in various formats. Additionally, students individually

record key content through note-taking using various learning strategies such as underlining, summarizing, creating organizers, etc. (Baldwin et al., 2019).

b) *Execution phase of the TPD-FLCW*

These are the activities that take place during the session. It comprises the dynamic processes of learning in a synchronous way in class.

(3) Feedback. This is the moment when the teacher monitors and attends to the individual learning of the students, after having reviewed the materials. Feedback is provided through forums, workshops, gamification strategies, personalized tutorials, among others that actively involve the students. Cognitive, emotional, social, and structural dimensions are addressed.
(4) Workshops. This represents the specific activities that students carry out to apply their theoretical knowledge to writing. The workshops are developed through the active methodology of Collaborative Writing, under the guidance and direction of the teacher. Students apply their knowledge to the presentation of a product that demonstrates their socio-constructive learning (progress of the written text, elaboration of the outline of the writing plan, register of sources consulted, among others).

c) *Exit phase of the TPD-FLCW*

It consists of actions that are executed at the end of the learning sessions.

(5) Assessment. It consists of collecting information on the learning achieved by students to obtain a standard. It is carried out through formative and summative assessment. The first one allows knowing the learning achievement of the students according to the difficulties and progress. In addition, it examines what they learned and could learn through self-assessment, co-assessment, and heteroassessment (Traverso, 2023). The latter identifies their academic progress based on criteria outlined in the assessment instruments.
(6) Metacognition. It represents the moment when students reflect on their learning processes through self-critical questions, what they learned easily and where they had difficulty, as well as the use of solution strategies. This stage is composed of questions oriented to metacognitive awareness, which consists of knowing their potential and limitations for learning, and extension activities for metacognitive control characterized by assuming an active and participatory role in their learning.

3. Development phase

a) *Organisation of the content for the sessions*

A guide of 09 learning sessions on the content of the academic essay has been developed with the application of the TPD-FLCW (Table 4).

Table 4
Content of learning sessions with TPD-FLCW

Session	Content	Preliminary phase*	Implementation phase**	Exit phase**
01	Academic essay. Characteristics, types, and structure.	Analysis of textual and audiovisual content. Response to a four-question sheet on the content and note-taking.	Feedback with 4 questions, development of multiple choice questionnaire, identification of topic, thesis, main argument of paragraphs (in teams).	Evaluation with observation sheet, metacognitive questions, crossword reinforcement, and a preview of the next session.
02	Text properties: appropriatenes s, correctness, coherence, and cohesion (reference, substitution, ellipsis, and markers).	Synthesis of important ideas from textual and audiovisual content of Youtube video and answer to 4 questions, note-taking.	Feedback with 4 questions, solving a 10-question questionnaire with Google Forms, participation in Jamboard, rewriting incoherent texts, and creating paragraphs with non-cohesive sentences (in teams).	Assessment of texts with a checklist, response to 3 metacognitive questions, and reinforcement activity with the creation of a coherent and cohesive text.
03	Writing process: Planning (brainstorming and research), understanding sources, processing information, and developing the outline.)	Synthesis of ideas from lecture material and answer to 4 questions, note-taking	Participation and socialization of previous writing concepts in Padlet, feedback questionnaire in Moodle, planning of essay "What does the 21st-century engineer need to practice his profession properly?"	Evaluation of the planning scheme with a checklist, response to 4 metacognitive questions, socialization of the scheme in a forum, and evaluation of work (co-evaluation).
04	Textualisation, structure (contextualisa-tion, thesis, and mapping), and types of introduction.	Viewing and taking notes on the material. Analysis of the 5 introductory examples.	Response to 3 content questions, participation in Kahoot development, creation of Google Docs in teams, and choice of topic, thesis, and introduction writing.	Evaluation of the introductory paragraphs with the checklist, response to metacognitive questions, and assessment of the introduction of other teams.
05	Citations (direct and indirect) and references in APA format.	Analysis of the videos and taking notes and practical exercises.	Response to 4 content questions, Wordwall feedback, and APA citation and referencing exercise.	Assessment of citations and references with the checklist, response to metacognitive questions, and progress of the essay.
06	The development of the academic essay. Elements of the paragraph and argumentative strategies.	Analysis, note-taking, and reflection on the examples of argumentative structures.	Response to 4 argumentation questions, feedback with Kahoot, construction, and outlining of 8 paragraphs.	Evaluation of paragraphs and response to metacognitive questions, socialization, and analysis of paragraphs in the forum.

Session	Content	Preliminary phase*	Implementation phase**	Exit phase**
07	Counter-argumentation and conclusion (reiteration of thesis, synthesis of arguments, and reflection)	Analysis and note-taking of the materials and reflection on the types of conclusion.	Response to 4 counter-argument/conclusion questions, Kahoot feedback, and paragraph writing.	Assessment of counterargumentation and conclusion paragraphs with the checklist, response to metacognitive questions, and socialization and comments in the forum.
08	Revision process. Syntax, spelling, and lexis.	Analysis and note-taking of the "Revision" material. Reflection on revision strategies.	Response to 5 content-related questions, Moodle feedback, anonymous sharing of the academic essay, and assignment of papers for review.	Evaluation of the quality of evaluators' suggestions with observation guide, response to metacognitive questions, and essay correction.
09	Intra-group agreement. Intra-group review strategies. The publication process.	Analysis of the material "Intra-group agreement and steps for publication".	Response to content-related questions, oral feedback, application of intragroup revision techniques, and presentation of the final work with similarity report and journal elaboration.	Self-assessment of the quality of their academic essay and contribution to the team with a self-evaluation form, response to 3 reflection questions, and presentation of the journal.

Note 1. The content used in each pre-phase was audio-visual, textual, and slides. In the exit phase, the next session was previewed.
Note 2. * Each session in this phase is worked on individually, asynchronously, and at home (online). ** Each session in this phase is worked on in teams, synchronously, and in class (online).

b) *Validation of the Technopedagogical Design FLCW*

The agreement among judges is high (CVC > 0.90) for all criteria (Table 5). Furthermore, the assessment among these criteria shows significant and acceptable agreement ($p > 0.05$, $k > 0.3$). Therefore, it is possible to affirm that the TPD-FLCW demonstrates adequate content validity and presents the conditions for implementation in the experimental group.

Table 5

Agreement among expert judges

Criteria	S_{x1}*	Mx**	Epi***	CVC_i	CVC_{tc}
Rel	73	4.563	5.4E-20	0.913	0.913
Jus	73	4.563	5.4E-20	0.913	0.913
Sub	74	4.625	5.4E-20	0.925	0.925
Coh	75	4.688	5.4E-20	0.938	0.938
Str	75	4.688	5.4E-20	0.938	0.938
Suf	74	4.625	5.4E-20	0.925	0.925
Met	78	4.875	5.4E-20	0.975	0.975
Res	73	4.563	5.4E-20	0.913	0.913
Upd	77	4.813	5.4E-20	0.963	0.963
Lia	76	4.750	5.4E-20	0.950	0.950
Acf	74	4.625	5.4E-20	0.925	0.925
Eva	73	4.563	5.4E-20	0.913	0.913

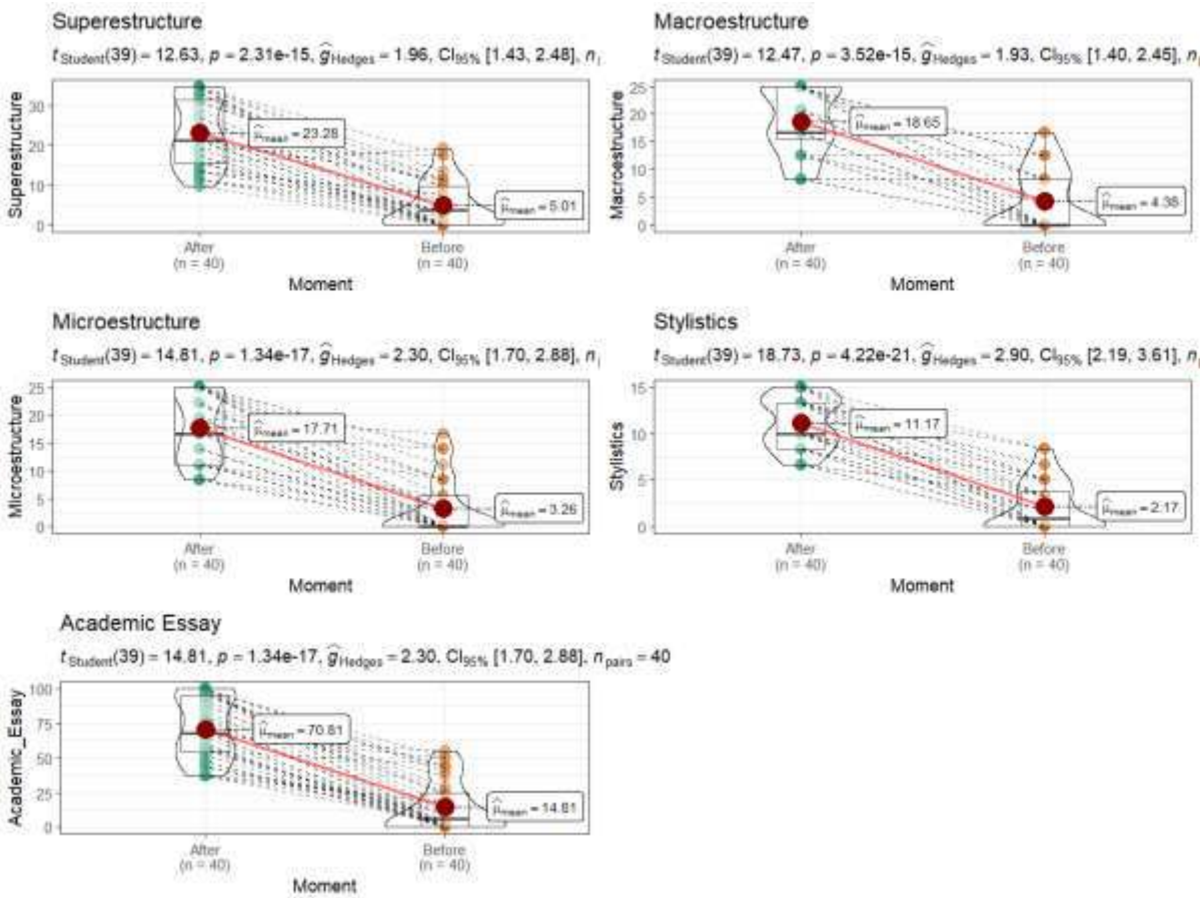
Criteria	S_{x1}*	Mx**	Epi***	CVC_i	CVC_{tc}
Via	76	4.750	5.4E-20	0.950	0.950
CVC Total	CVC = 0.934				
K_{Fleiss}	K = 0.392, *p* = 0.000, IC95% L = 0.342 - H = 0.442)				

Note 1. * summative score, ** sum/maximum value of judge, *** error probability
Note 2. Rel: relevance, Jus: justification, Sub: substantiation, Coh: coherence, Str: structuring, Suf: sufficiency, Met: methodology, Res: resources, Upd: update, Lia: linguistic aspects, Acf: academic format, Eva: evaluability, Via: viability

4. Implementation phase

The results of the experiment show significant improvements in superstructure, macrostructure, microstructure, and textual stylistics ($p < 0.05$; $\hat{g}_{Hedges} > 1.20$), as well as in the overall average of the academic essay (Figure 3). These changes explain that with the TPD-FLCW intervention, students write their individual academic essays better.

Figure 3
Comparison of evaluation before and after the TPD-FLCW



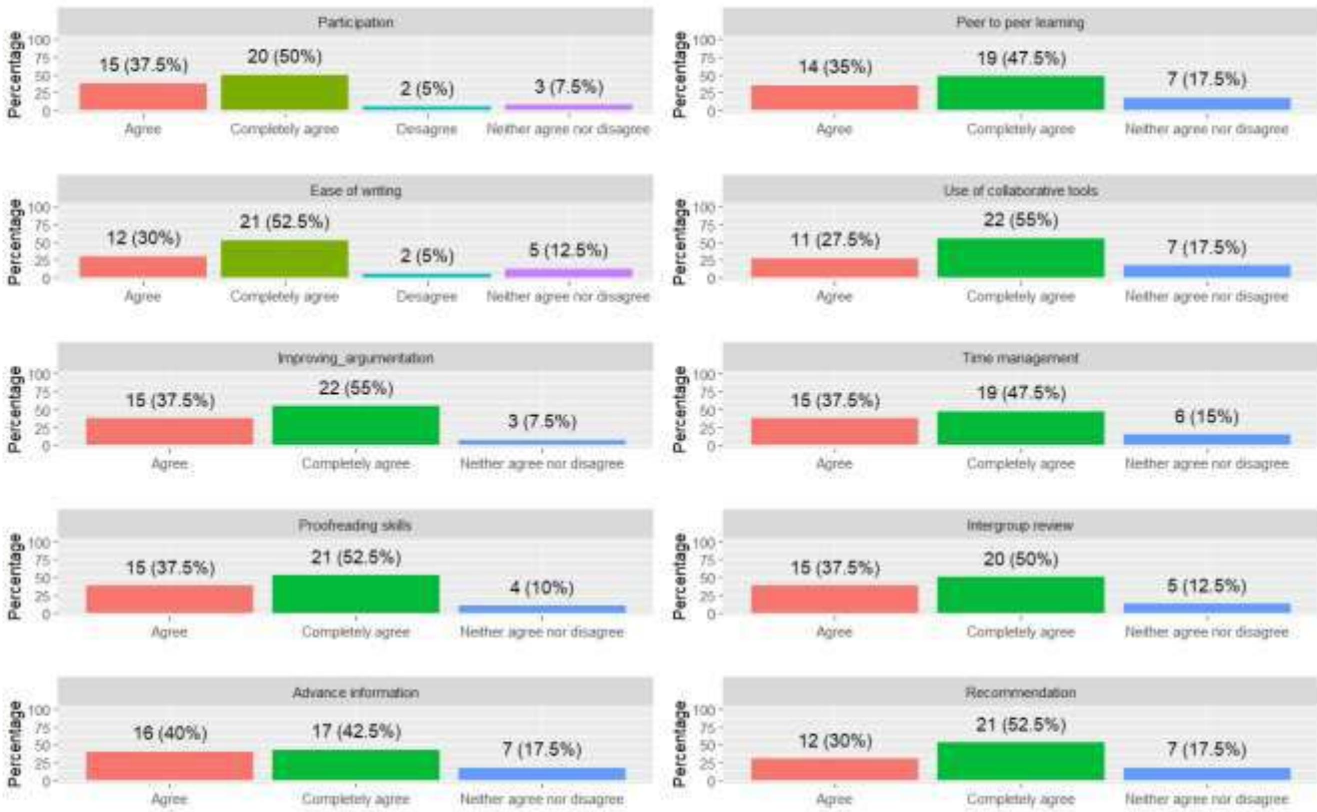
5. Evaluation phase

a) *Quantitative evaluation*

The results highlight that almost all students (≥ 90 %) consider that they at least agree that they have improved their argumentative and proofreading skills. The positive trend extends to more than 80% affirming that they actively and collaboratively participate, find team writing easier than individual writing, use communicative tools, manage time, revise their texts, and maintain originality (Figure 4). They agree with receiving information in advance and recommend using TPD-FLCW in other texts.

Figure 4

Students' assessment of the TPD-FLCW



b) *Qualitative evaluation*

The analysis of the students' assessment is carried out based on 3 sections:

Before the TPD-FLCW

The students claim that initially, they faced difficulties due to a lack of knowledge of the formal writing process. The lack of training in basic education regarding the attainment of writing competence in argumentative texts, citation and reference norms, and information retrieval conditions the rigor of their essays. The absence of a thesis statement left their arguments disoriented. Some statements made by students were as follows:

- «[...] nunca, o sea, no lo había hecho, no lo había realizado [...]» ["never, I mean, I had never done it, I had never done it before"] (E07).
- «[...] al momento de revisarlo me di cuenta que ni siquiera había usado formato APA, que no tenía referencias bibliográficas y que no me había apoyado en ninguna cita o no había investigado lo suficiente, que simplemente lo que había hecho es, digamos que, hasta una opinión personal, sin ningún fundamento teórico que pueda defender mi postura [...]» ["when I reviewed it, I realized that I hadn't even used APA format, that I didn't have bibliographic references, and that I hadn't relied on any citations or hadn't researched enough, that basically what I had done was, let's say, purely a personal opinion, without any theoretical foundation to defend my stance"] (E02).
- «[...] en ese ensayo, me hizo falta tener la originalidad, se podría decir, porque prácticamente, como dije, me guiaba de otro ensayo [...]» ["in that essay, I lacked the originality, you could say, because practically, as I said, I was guided by another essay"] (E01).

Another point that frequently emerged in the responses was the lack of originality. Papers submitted to the Turnitin plagiarism detection system reported similarities exceeding 50%. The coincidences originated solely from web pages or blogs (without authorship or publication date), which explains the limited development of informational competencies. Furthermore, their unfamiliarity with the chosen topic led them to search various sources from which they extracted fragments to include in their essays.

- «[...] sacaba quizás muchas cosas de Internet, las unía y ponía las referencias y, pensaba que esa manera iba a estar bien hacer un ensayo [...]» ["I would take maybe a lot of things from the internet, put them together, and add references, and I thought that way it would be fine to write an essay"] (E03).
- «[...] lo que hizo falta más, ser más propio de mí, porque si netamente me basé en información de páginas y sobre todo pienso que le faltó ser más verídico porque no tuve fuentes de páginas confiables o de revistas, de repositorios [...]» ["what was missing was more, to be more of my own, because if I purely relied on information from websites and especially I think it lacked credibility because I didn't have sources from reliable websites, journals, or repositories."] (E06).

After the TPD-FLCW

With the TPD-FLCW, students reported improving their writing skills, due to the planning process focused on intra-group interaction and recognition of each member's writing strategies. They perceived constant peer feedback, taking an active role in empowering them to achieve proficiency. Although the distributions of certain paragraphs were done individually, this product was reviewed in detail by the whole team. The classroom climate in the groups generated positive, comfortable, and adequate satisfaction.

- «Empezando por la planificación, la ventaja que encontré es que todos interactuamos y dábamos bastantes ideas» ["Starting with the planning, the advantage I found is that we all interacted and gave plenty of ideas"] (E01).
- «Todos trabajamos y aportamos adecuadamente. No hubo un retraso. Creo que sí se logra aprender un poco, ya que tal vez alguien siempre tiene un poquito menos de entendimiento al momento estructurarlo (el ensayo) y lo corregimos juntos [...], de este modo y así se hace una retroalimentación exactamente en conjunto» ["We all worked and contributed adequately. There was no delay. I think we did manage to learn a little bit, because maybe someone always has a little bit less understanding when structuring it (the essay) and we corrected it together [...], in this way and that way we get feedback exactly together"] (E04).

Regarding the methodological procedure, the students were satisfied. They were able to acquire the content knowledge before the beginning of the class, and during the session, they shared the notes. Thus, the essay writing scenario was clarified. In addition, the didactic presentation of videos, text, and slides was indispensable for cognitive learning. However, this was complemented by registration strategies (note-taking) for in-class consultation and workshop development.

- «Yo tomé apuntes a todos los vídeos, a pesar de que lo teníamos en vídeos y en documentos PDF [...] cualquier duda lo consultaba en clase para tenerlo claro» ["I took notes on all the videos, even though we had them in videos and PDF documents [...] I consulted any doubts in class to clarify them"] (E03).
- «Esos materiales han sido precisos y que hayan estado de manera audiovisual y también escrita nos sirve a los estudiantes porque, por ejemplo, yo prefiero leer, pero tal vez alguien prefiere escucharlo o en diapositivas» ["These materials have been precise, and having them both audiovisually and in written form serves us as students because, for example, I prefer to read, but perhaps someone else prefers to listen to it or see it in slides"] (E05).

Differences between before and after the TPD-FLCW

The students identified significant changes in their learning when comparing the texts they wrote at the beginning (pre-test) with those afterward (post-test). They recognized that their first essay lacked a thesis, organization, and structuring of the paragraphs according to the superstructure of the essay (introduction, development, and conclusion). They even noticed an improvement in presentation formalities (margins, indentation, correct use of citations, etc.).

- «En el primer ensayo, no podía identificar la tesis porque —de hecho, observé que ni siquiera tenía una tesis y tampoco tenía un mapeo–. Entonces, sí hubo bastante diferencia. El ensayo que elaboré ahora (postest), siento que está muy bien» ["In the first essay, I couldn't identify the thesis because - in fact, I noticed that it didn't even have a thesis and it didn't even have a mapping. So there was quite a difference. The essay that I crafted now (post-test), I feel, is very well done"] (E01).

- «El primer ensayo que hice no tenía como tal una estructura o sea tocaba temas en general, los párrafos no tenían un orden, no tenían las partes que corresponden, no tenían la introducción, solamente desarrollo, pero ahora con el nuevo trabajo ya tiene la introducción, la idea principal, el desarrollo del párrafo, la conclusión» [The first essay I did did not have a structure as such, that is, it covered general topics, the paragraphs did not have an order, they did not have the corresponding parts, they did not have the introduction, only development, but now with the new work, it has the introduction, the main idea, paragraph development and the conclusion] (E06).

DISCUSSION

The research was aimed at developing and validating the TPD-FLCW to promote the development of academic writing (academic essays). Based on flipped learning and collaborative writing, emphasis is placed on a design that guides the role of the teacher and student in each of the phases that constitute its implementation.

The TPD-FLCW was implemented to address the issue of academic writing. Difficulties in the development of academic writing competence were identified. Lack of understanding of the argumentative process, citations, and references promoted inappropriate practices such as academic plagiarism (Acosta et al., 2023; Festas et al., 2023). In response, the TPD-FLCW was established as a proposed solution that required an organized and systematic process for writing production learning. The diagnostic evaluation served as input for session planning (Hess & Moseley, 2016).

The TPD-FLCW significantly contributes to overcoming difficulties in students' academic essay production. This is consistent with literature that has implemented FL or CW (Khojasteh et al., 2021; Roohani & Rad, 2022). The improvement is due to the development of individual activities (before class) and collaborative work (during class), as supported by FL. Individual note-taking also contributes to content retention (Courtney et al., 2022). Therefore, it was crucial to encourage students' autonomy. At the end of each session, the teacher provided directions for the next one.

Teamwork methods constitute an efficient mechanism for learning. Although some team members had disagreements, the methodology allowed them to engage in dialogue and propose feasible solutions. Disagreements can be seen as a means to achieve objectives (Godoy, 2021). Among the strategies implemented by team members were shared reading, peer feedback, cloud-based information sharing, role exchange, and internal decision-making. Collaboration among team members stimulates the use of techniques and strategies to provide solutions to problems that arise (Laal & Ghodsi, 2012). However, this is achieved because of the interest of all members. In this regard, the role of the teacher represents an essential scaffolding to consolidate students' commitment to their learning and their team (Amineh & Asl, 2015).

Additionally, the students' assessment of the TPD-FLCW was positive, not only due to the cognitive improvements or achieved competencies but also because of their emotional state and satisfaction with the team. The cognitive, procedural, and emotional advantages stem from the disruption of the traditional class structure

(Ebron & Mabuan, 2021). During the preliminary phase of the proposal, students acquired knowledge at their own pace and preferred style (visual or auditory). This is because when the time and manner are in line with the students, they gain a greater confidence that is conducive to learning during the lesson (Owen & Dunham, 2015). Thus, virtual workspace areas were not only spaces for academic work, but also for socialization—an aspect that contributed to team engagement.

CONCLUSIONS

The study has led to the creation of a new technopedagogical design aimed at academic writing for university students in their early cycles. This design has been beneficial for improving academic essays.

The TPD-FLCW is significant and applicable in virtual educational settings; therefore, it constitutes a guide for pedagogical experiences aimed at addressing the issue of academic writing. Although the presented experience focuses on essay production, its implementation is not limited to other forms of written production. The didactic advantage that the TPD-FLCW can offer lies in focusing the writing activity on its natural (practical) form within the collaborative process.

It has been explored that the active role in learning is shared by both students and teachers. The former is a participative and autonomous agent; the latter creates the conditions for learning through material planning and feedback instruments. Students positively value the way the teacher plans, directs, and provides feedback in class, but they also appreciate the commitment of their teammates during the writing workshops.

Some limitations of the study are associated with the sample size of the experimental group. Although they are students from different engineering disciplines, it is necessary to have more empirical evidence in multidisciplinary settings and with a larger number of participants. Additionally, the interview was conducted with a small group, but it would be advisable to know the perception of all participants. Future studies could implement interventions in non-university higher education contexts, as well as in the production of other types of academic texts such as monographs, scientific articles, or theses while maintaining the processes and functions of the teaching staff to extend the empirical evidence and evaluate the team strategies employed by students more effectively within the implementation of the TPD-FLCW.

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Is collaborative learning inclusive? Case study on its application in a fully online university

¿Es inclusivo el aprendizaje colaborativo? Estudio de caso sobre su implementación en una universidad en línea

José Israel Reyes - *Universitat Oberta de Catalunya, UOC (Spain)*
Julio Meneses - *Universitat Oberta de Catalunya, UOC (Spain)*

ABSTRACT

Online collaborative learning offers several advantages for the development of learners' competencies, including cognitive, metacognitive, and affective aspects. However, its implementation in teaching is challenging, especially regarding the participation of learners with disabilities. Professors play a crucial role in promoting the equitable participation of all students. In this investigation, we conducted a case study focused on exploring the perspectives of 12 professors from an online university with experience in supporting learners with disabilities in collaborative activities. We carried out semi-structured interviews, which were analysed using thematic analysis. According to our participants, there are limitations in terms of accessibility, flexibility, and socio-emotional aspects that hinder the full participation of some students in online collaborative learning. The role of professors as mediators, facilitators, guides, and learning managers often empower learners with disabilities to engage in interactive spaces, discussions, and teamwork activities. Collaborative learning requires strengthening the affective skills of all those involved, as well as making collaborative practices more flexible and providing a variety of media to enable everyone to participate. This poses a dilemma for professors, who have to balance the use of accessible and flexible practices with the promotion of emotional connections. Institutional efforts are therefore needed to make online collaborative practices suitable for all, and to provide professors with access to the appropriate knowledge, information, and resources that enable them to adopt an inclusive approach.

Keywords: distance education; higher education; group learning; online interaction; equal opportunities.

RESUMEN

El aprendizaje colaborativo en línea ofrece numerosas ventajas para el desarrollo de las competencias del estudiantado, abarcando aspectos cognitivos, metacognitivos y afectivos. No obstante, su aplicación en la práctica docente enfrenta algunos desafíos, especialmente respecto a la participación de los estudiantes con discapacidad. El profesorado desempeña un papel fundamental para promover la participación equitativa de todo el estudiantado. Esta investigación se basa en un estudio de caso centrado en explorar las perspectivas de 12 profesores de una universidad en línea con experiencia en el acompañamiento de estudiantes con discapacidad en actividades colaborativas. Realizamos entrevistas semiestructuradas, analizadas a través del análisis temático. Según nuestros participantes, existen limitaciones respecto a la accesibilidad, flexibilidad, así como referente a aspectos socioemocionales que dificultan la plena participación de algunos estudiantes en el aprendizaje colaborativo. Su rol de mediadores permite que los estudiantes con discapacidad a menudo se involucren en los espacios de interacción, los debates y el trabajo en equipos. El aprendizaje colaborativo requiere el fortalecimiento de las competencias afectivas entre todos los involucrados, así como la flexibilización de las dinámicas de colaboración y la diversificación de los medios de trabajo para favorecer la participación de todo el estudiantado. Lograr esto representa un dilema para el profesorado, quienes deben buscar un balance entre la accesibilidad de las prácticas y el fomento de las relaciones afectivas. Consecuentemente, es necesario un esfuerzo institucional para convertir en inclusivas las activades colaborativas y que el profesorado tenga acceso a los conocimientos, información y recursos adecuados para un enfoque inclusivo.

Palabras clave: educación a distancia; estudios universitarios; trabajo en equipo; interacción; igualdad de oportunidades.

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INTRODUCTION

Online collaborative learning or computer-supported collaborative learning (CSCL) is a constructivist approach in which learning is achieved through social interaction and the exchange of ideas, information, and opinions (Badia et al., 2017; Cress et al., 2015). Academic literature has highlighted the benefits and advantages of collaboration in online learning environments for learners' cognitive, metacognitive, social, and emotional development (Järvelä et al., 2016; Kumi-Yeboah, 2019). Research has also emphasised the effectiveness of collaborative learning in fully online or blended learning environments, citing an increase in professor-learner and learner-learner interactions (Castellanos Ramírez & Niño Carrasco, 2020; Wengrowicz et al., 2018). The literature also highlights the enhancement of learners' motivation to learn (Strauß & Rummel, 2021; Thomas & Thorpe, 2019), as well as their key role in knowledge building, the acquisition of meaningful learning, and the development of critical thinking and problem-solving skills (Saritama et al., 2022; Zhang et al., 2022). However, the discussion also focuses on the difficulties of implementing collaborative learning in online learning environments (Chen et al., 2021; Reyes et al., 2023), the exclusive use of cognitive and procedural approaches (Jeong et al., 2019; Lock & Redmond, 2021), the imbalance in learners' contributions (Capdeferro & Romero, 2012; Zapatero et al., 2022) and lack of innovation (Ruys et al., 2014).

Several types of students, including those living with disabilities, chronic illnesses, or mental health conditions, choose online higher education because of the advantages it offers in terms of flexibility (Fichten et al., 2020; Reyes et al., 2023). Thus, there is an urgent need for in-depth research into the strategies that online professors should use to facilitate the equitable participation of all learners in collaborative knowledge building. Supporting the diversity of learners entails considering aspects such as the accessibility of learning resources and materials, technical and emotional support, and, of course, pedagogical monitoring (Kocdar & Bozkurt, 2022; Reyes & Meneses, 2022). Ensuring that all learners have access to these conditions is crucial for the effectiveness and equity of collaborative learning (Kalir, 2018; Kumi-Yeboah, 2019). However, putting this vision into practice is extremely complex due to the diversity of learners' needs, requiring training, support, and resources for professors.

Some learners with disabilities may find it difficult to access resources and online learning environments (Reyes et al., 2022). For instance, students with hearing impairments struggle to communicate through audiovisual formats without textual support (Rao et al., 2021). Those with visual impairments tend to have difficulty accessing graphic and text-based resources that cannot be processed by text or screen readers (Rodrigo & Tabuenca, 2020). Furthermore, less visible groups such as those with learning difficulties, developmental disorders, and mental health conditions often face challenges in social interaction and collaboration, which can lead to socio-emotional problems (Gehret et al., 2017; Murphy et al., 2019). Previous research suggests that a considerable number of learners choose to study online to avoid the inconveniences of in-person social contact, such as stigma and discrimination (Melián & Meneses, 2022). Hence, their participation in certain activities, such as teamwork, could be challenging for them.

Online collaborative learning demands a high degree of autonomy and co-regulation (Badia et al., 2010). These demands may conflict with the needs of some learners, depending on their individual condition. For instance, students with neurodevelopmental and emotional regulation disorders often have difficulties with self-regulation, organisation, and planning (Dahlstrom-Hakki et al., 2020; Moon & Park, 2021). The needs of these learners clash with the competencies required for collaborative learning, as executive functions play an important role in collaborative knowledge building (Järvelä et al., 2016). Despite their importance in online collaborative learning, there is a lack of research on crucial topics such as self-regulated and co-regulated learning among learners with disabilities.

Online collaborative learning can facilitate learning and academic success, but focusing it on a non-inclusive approach can be an important cause for learners to drop out of university (Strauß & Rummel, 2021). Therefore, it is now a priority to take measures to promote equitable collaboration and supportive environments (Sánchez-Rojas, 2019). In this context, the role of professors as learning facilitators and guides in both organisational and personal aspects is crucial to ensure the full participation of all learners in social interaction and collaboration processes (Hernández-Sellés et al., 2023; Thomas & Thorpe, 2019). Professors need to adapt not only to the context of the learning environment, but also to the diversity of learners who opt for online higher education. Therefore, their responsibilities are wide-ranging and include designing and applying innovative learning strategies; creating suitable learning materials; managing, organising, and assessing learning; supporting learners; promoting motivation and self-regulation; and demonstrating a willingness to continuously improve their practice (Hernández-Sellés et al., 2023; Kalir, 2018).

Research context

This research was carried out in a Spanish online university, which currently has the second highest number of learners with disabilities in Spain. The university's educational model puts the learner at the centre and is based on four pillars: flexibility, collaboration, interaction, and personalised learning. To implement this model, the university offers a wide range of digital resources in multiple formats, a fully online learning environment, communication tools to promote asynchronous interaction and collaboration, and student support from professors, academic advisors, and student services. In terms of teaching staff, the university has two distinct figures. Full-time professors are responsible for designing curricula, managing, and preparing learning resources and materials, and leading teaching and assessment. Part-time professors then teach the courses in the virtual classrooms. This research focuses on the latter group of professors who supervise, assess and support learners' activities.

Research aim and questions

Learners with disabilities are often invisible in online universities, so research on their inclusion in collaborative knowledge-building processes is virtually non-existent. Therefore, the aim of this study is to analyse professors' perceptions of their role in promoting the involvement of learners with disabilities in online collaborative practices. By focusing our research on improving collaboration and social interaction in online higher education, we can identify the conditions that can make online collaborative learning inclusive for all learners.

The following questions guided the research process:

a) How do professors address the inclusion of learners with disabilities in interactive and collaborative activities in online higher education?

b) How do professors perceive the involvement of learners with disabilities in online collaborative learning in a fully online learning environment?
c) How can professors and online universities promote the equitable participation of all learners in interactive and collaborative learning activities?

METHODOLOGY

This research is based on the case study design (Yin, 2009), as our aim was to analyse the processes and dynamics within the researched institution. Our analytical framework is centred on an essentialist approach, where exploring participants' specific perspectives serves as the primary source of knowledge. Analysing these experiences and viewpoints is important for understanding the underlying reasons for particular behaviours and decisions (Braun et al., 2015). In this regard, this type of research helps us to understand why things happen and, consequently, to suggest improvements in teaching practice.

Participants and procedures

The research team first defined the criteria for recruiting participants: (1) at least 2 years' experience as online professors; (2) having implemented collaborative learning activities in their courses; and (3) having experience with learners with disabilities in such courses. After the university's Ethics Committee approved the study, part-time professors were invited to participate. Those interested voluntarily contacted the main researcher to express their wish to participate. Twelve of them were then selected (two from each faculty) according to the established criteria. This strategy enabled us to capture a diversity of perceptions and opinions, taking into account the differences that exist across disciplines and course content. Participants were informed of their rights and conditions of participation prior to the study through an informed consent form, which guaranteed their confidentiality and data protection.

Data were collected through semi-structured interviews conducted via videoconference. The interview protocol was designed based on international literature and then pilot-tested to ensure its clarity and consistency. The themes of the interviews were: (a) promoting interactivity and collaboration among students; (b) experiences of supporting learners with disabilities in interactive and collaborative processes; (c) professors' perceptions of the involvement of these learners in collaborative spaces; and (d) thoughts, challenges and needs around promoting the inclusion of diverse learners in collaborative learning practices. The interviews lasted between 45 and 60 minutes and were transcribed verbatim for later coding and analysis.

The information collected was analysed inductively following the procedures of thematic analysis (Braun et al., 2015; Braun & Clarke, 2006). In line with an essentialist approach, our aim was to orient the analysis towards an experiential dimension, in which we mirrored participants' opinions and viewpoints according to their own realities. Thus, after an exhaustive review and as a product of iterative interactions with the dataset, we focused on identifying participants' experiences, perceptions, and opinions in relation to the research questions, following the six phases of thematic analysis. In this process, the main researcher developed an initial proposal which was discussed, revised, and improved in collaboration with the second author, resulting in the definition of the subsequent analytical themes.

FINDINGS

The findings are structured around three main themes within which we exhaustively analyse the experiences of our participants. Within the first theme, "Professors as facilitators of online collaborative learning", we analyse the role of professors in managing tools, strategies, and collaborative processes in both pedagogical and technological dimensions. We also explore affective issues as latent aspects that prove crucial in promoting social interaction and collaboration in a fully online learning environment. Within the second theme, "Involvement of learners with disabilities in collaborative knowledge building", we analyse professors' perceptions of learners with disabilities' participation in discussion and interaction spaces and teamwork activities as the main sources of collaboration in a fully online university. Here, we focus on some critical issues to consider when implementing online collaborative learning, such as the organisation, flexibility, and personalisation of collaborative work dynamics. Finally, within the third theme, "Adopting an inclusive approach to online collaborative learning", we address our participants' reflections about some future lines of work aimed at both supporting the work of professors and incorporating measures to enable the fair, equitable and effective participation of all learners in collaborative learning. In this last theme, we discuss the role of institutions in applying inclusive online collaborative learning, which is relevant not only to fully online universities, but also to those that operate on a blended learning model.

Professors as facilitators of online collaborative learning

Interaction and collaboration tools do not always meet learners' needs. We found that some informatic applications create accessibility barriers for some learners, depending on the type and severity of the disability they live with. According to our participants, these difficulties are usually experienced by learners with sensory (visual, hearing, and speech) disabilities, for whom certain collaborative environments and tools become disabling. There are courses that require the use of voice-based interaction tools, which create accessibility challenges for learners with hearing and speech impairments. The format in which activities are presented may be problematic for some learners, while enabling access for others. For instance, forums and discussions usually rely on textual interaction, which encourages the involvement of most students, but often hinders the participation of those with visual and learning difficulties, as well as those with physical disabilities that limit their fine motor skills. In this regard, professors have an important role to play in finding solutions, either by suggesting tools and resources to enable the participation of those learners who have previously indicated a specific need, or by offering them alternative learning activities.

Typically, professors solve accessibility problems through accomodations that they manage as needed. According to our participants, this type of action is usually very useful and, if properly handled, helps to facilitate the inclusion of learners with disabilities in collaborative learning activities. The experience of participant (P) 7 illustrates this point: "After we managed the accommodation [this learner] requested, she didn't contact us again. She presented the assignments, was involved in the group discussions… Everything was fine". However, there are conflicting situations that concern professors. Firstly, online learning makes it possible for some learners' needs to go unnoticed unless they ask for support beforehand, which is not always the case. Therefore, by the time professors receive a request for accommodation – very often from their own learners – learning or assessment activities have already been designed without considering these learners' needs. In these cases, professors feel compelled to improvise in order to offer a partial temporary solution. Secondly, the skills to be developed can conflict with the learner's needs, so professors have no alternative but to segregate and offer these learners another activity to do individually. P2 commented on this: "This person with hearing impairment can do the recordings, but everything is done individually; she cannot interact orally with the rest of the learners, nor can she do the listening because it would be so challenging for her".

The role of professors in promoting online collaborative learning and interaction is closely linked to affective factors. For one, creating an environment of human warmth that fosters mutual support, empathy, respect, and harmonious coexistence is critical and a key part of the process. "When you put yourself in someone's shoes, especially someone facing difficulties, you understand many things. In an online environment that is very impersonal, it is essential for the student to always feel supported by their professors" (P2). Secondly, fostering interpersonal relationships among learners in a fully online learning environment is quite a challenge nowadays, given people's lack of time and the physical and emotional distance enforced by the environment, which even affects professors. Lack of interest in socialising is also a barrier. However, this study highlights some very promising experiences of collaboration and mutual support among learners. According to our participants, these synergies, although they vary across learner cohorts, are necessary to make collaborative learning a reality in online learning environments. P9 said:

> This is the first time a student has written to me and said: 'Several students have been talking'. Interacting with each other helps them, because at the end of the day, if you only have contact with professors, you don't create those [social] bonds that are now being built in the classroom.

Our participants place a high value on both the professor and social presence. These two aspects go hand in hand in promoting interactivity and collaboration in a fully online learning environment where everyone's involvement is sought. Professors' mediation is crucial in motivating learners to make such connections. They use their creativity and good will to suggest strategies for promoting interactivity in the classroom. P6 said: "We've implemented several initiatives to liven up the forum in order to maintain active participation in the classroom and prevent students from feeling isolated. These include step-by-step exercises and a weekly mathematical challenge directly related to the current course material." Other strategies used by professors include personalised emails and interacting with the entire classroom through the various official channels, be it text-based messages, pre-recorded videos, or even synchronous videoconferencing. "We organise a reflective discussion. We provide some videos, articles, and questions and the students share their opinions. However, participation is voluntary, so some people join and others do not" (P4).

Communication between professors and learners has to be dynamic and fluid on the one hand, and accessible and usable on the other. In this regard, professors have a transcendental role to play in providing a variety of media and formats to facilitate learner interactions in the appropriate spaces. Participants described strategies such as supplementing text-based messages with voice notes, using live captions in videoconferencing, and combining synchronous audiovisual interactions with textual clarifications. Communicating through audiovisual formats allows for more dynamic and direct interaction, which additionally encourages an emotional bond with learners.

P1 commented: "I communicate using voice notes because it saves me time and is more effective for communication because it's more human; I can convey emotions and it helps students to better understand what I want to express." Furthermore, this interaction helps to promote learners' involvement in collaborative practices. "I always point out on the board that we are building knowledge with this type of activity; together we provide ideas to construct it" (P8). However, our participants are aware that bringing all these aspects together requires a significant investment of time and resources.

Involvement of learners with disabilities in collaborative knowledge building

Engaging learners in interactive activities in a fully online learning environment is still challenging for everyone. Professors have yet to find the formula to recreate the synergies that are easily developed in a bricks-and-mortar university: "I think the contact is very cold online. In the end, you upload the learning material and [the learners] have to figure it out for themselves. The only interaction between professors and students is through emails" (P4). In this respect, our participants make an important effort to organise the discussion spaces carefully to facilitate their usability. It is also important to focus discussion topics as much as possible to avoid an overload of messages and to reduce frustration and overwhelm among learners. P5 described this issue as follows:

> We have to be a bit careful with discussions. If a learner logs in, has very limited time, and sees a forum with 82 messages, I think it will only cause them distress. Moreover, the content of these forums is also somewhat scattered, with everyone saying whatever comes to mind.

The potential accessibility problems that these same learning environments can cause make it difficult for learners with disabilities to participate, thus creating an equity gap. Professors adopt measures such as redesigning learning activities and personalisation to promote inclusion. Among other examples, P8 explained: "We focused the debates on more conceptual discussions rather than image analysis, so that this student [with visual impairment] could participate". In any case, it is important to emphasise that it is usually not the learners' conditions that create barriers, but the environment. According to the participants, some learners with disabilities develop coping strategies that rely on proactivity, rigour, and persistence to overcome the obstacles they encounter. For instance, P7 commented on a learner with dyslexia: "She was fully aware of what this disability meant. So, she worked carefully on her contributions; they were perfect because she read them, reread them... She had to analyse them very well before posting."

According to our participants, online discussions are a very effective strategy for collaborative knowledge building. There are both assessable and non-assessable ones, with the latter having a particularly low level of learner participation due to the lack of gratification. Professors highlight two specific aspects: the wealth of ideas and the spontaneity with which learners express themselves. "In the field of design and communication, things are made up of criteria, colours, sensations, and you see [the learners] discussing the topic. I think that helps them a lot" (P7). The participation of learners with disabilities in these spaces varies, although our participants feel that it is not necessarily related to their condition. The exception is students with mental health conditions, such as neurodevelopmental, emotional, and behavioural disorders, who usually find it difficult to participate in online collaborative learning activities. In our participants' experience, the participation of these learners in discussion spaces is very limited and most of them are reluctant to participate in teamwork activities. Faced with these difficulties, professors feel caught between a rock and a hard place. On the one hand, their empathy and willingness to find a solution are paramount. On the other hand, they feel that they lack the preparation and resources to intervene.

Teamwork is the most challenging activity to promote collaborative learning with students with disabilities. According to our participants, this kind of dynamic affects learners' flexibility and pace of work. Students with disabilities tend to work more slowly than students without disabilities due to circumstances such as mobility issues, mental crises, physical discomfort, and cognitive limitations caused by medication. In this respect, our participants emphasise that the use of text-based and asynchronous tools for collaboration helps to mitigate these difficulties. The professors' experience suggests that working on shared documents tends to be quite compatible with inclusive collaborative learning, although they acknowledge that students sometimes use other media, such as video calls and instant messaging platforms, to organise their work.

However, carrying out text-based and asynchronous collaborative activities with all learners is controversial among professors. This ambivalence is rooted in the nature and characteristics of the courses. Professors from fields such as art and design are very satisfied with the way asynchronous discussions take place in their classrooms. In contrast, professors from fields related to critical thinking or with a technical approach tend to criticise the quality of asynchronous discussions or do not consider using these strategies for pedagogical purposes. P3 shared an opinion on this:

> In this asynchronous discussion, each student contributes. I think it's very limited in terms of working with the content. Often students come in when they can, post their contribution, but it's difficult to create a truly interactive dynamic and debate among them, let alone with the professor.

Professors are aware of the potential difficulties of online collaborative learning for certain learners, depending on their disability. P3 reflected: "We send the learning materials to the students, who later work on them through debates and teamwork, but when it comes to internalising certain content, it is more complex. These dynamics can create barriers for learners with certain disabilities". The digital aspect of online learning, together with asynchronous interaction, sometimes limits the ability of professors to mediate and create a warmer learning environment where each learner's participation is equally encouraged. Inclusion strategies do not have to be exclusive to learners with disabilities. Our participants described some measures that can help to create a learning environment with more closeness among learners before moving on to teamwork activities, although there are also concerns that such measures are not enough. P10 described her experience as follows: "In the course forum, apart from the presentation of the course, learners have to choose some priorities, their favourite aspects, topics, interests, etc. and find other classmates with similar affinities. From here, we suggest the formation of groups."

Adopting an inclusive approach to online collaborative learning

Creating interactive learning environments that focus on fostering collaboration is crucial in online higher education. However, in order to move towards an inclusive collaborative approach, it is necessary to go beyond the inclusion of interactive spaces in the design of virtual classrooms. In this regard, professors stress the importance of "creating an environment that inspires confidence" (P10), so as to encourage support seeking and participation among learners. P5 said: "In the case of mental illnesses, I believe that students need to share their issue with the professor, not to receive preferential treatment, but to feel heard, valued, and at ease."

Considering the benefits of online collaborative learning for developing competencies, both professors and institutions should aim for a change in teaching practice. According to our participants, it is crucial to ensure that tools, resources, and collaborative activities are based on universal accessibility. "I think accessibility is paramount nowadays, especially for an online university. It needs to be done right now" (P2).

Given the wide range of needs, "Each of the measures implemented can be inclusive for some learners and a barrier for others" (P3), so addressing this requires careful planning that takes into account the accessibility needs of all learners. Providing flexible and diverse media and formats would promote a better experience for all learners: "For [learners with disabilities], it would be advisable to have various channels of communication with students, depending on what they feel most comfortable with or find most useful, combining the written with the visual" (P12). Our participants also believe that it is necessary to listen to students with disabilities, and that no one is better placed to express their needs than the person living with the condition.

The role of professors is key to making inclusive collaborative learning a reality, although institutional support is also important. It is essential that all professionals with responsibilities related to the design of learning activities, resources, and media used for collaborative learning work together with practitioners. It is also important to involve other stakeholders who can bring their ideas to the search for better solutions for learners. For instance, the involvement of academic authorities and learning programme directors is very helpful in both governance and decision-making processes. "We had a student with generalised anxiety disorder. There were several meetings with those involved in managing the degree programme where all parties discussed and agreed on how to ensure her participation in all activities, but it wasn't easy" (P11).

DISCUSSION

Professors play an essential role in promoting inclusive collaborative learning in online higher education. Their contribution to managing collaboration tools, organising groups, monitoring learning and assessment activities, and promoting social interaction is crucial. These tasks become complex when the aim is to include all types of learners. In this regard, professors should shift their role to that of a learning facilitator (Hernández-Sellés et al., 2023; Zhu & Ergulec, 2023). In addition to being experts in their field, our findings suggest that professors should focus on managing learning tools and resources to make them fully accessible, promoting learners' self-regulation, and encouraging the equitable involvement of all learners.

Our research shows that the role of the professor in inclusive collaborative learning is more than delegating activities and assessing learners' performance; it also involves leaning into the emotional and affective aspects of teaching. It is important for learners with disabilities to have an inclusive environment to actively participate in online collaborative learning activities (Reyes et al., 2023). In line with Sánchez-Rojas (2019), professors should consider aspects such as empathy, cordiality, and the ability to connect with learners. In addition to generating learning, it is also important to promote affective relationships and camaraderie among learners in order to foster collaboration (Castellanos Ramírez & Niño Carrasco, 2020). However, fostering this connectedness is a complex and demanding task, which requires designing practices that are equity-oriented (Kalir, 2018) and seeking resources and support mechanisms that facilitate the effective and equitable participation of all learners in collaborative knowledge building.

Tensions between teamwork and the needs of learners with disabilities are evident in this study. Professors often have to mediate issues such as accessibility and social pressure in order to include these learners in group activities. We have found that professors perceive greater difficulties in involving learners with mental health conditions and neurocognitive disorders in teamwork activities and discussions. It is therefore necessary to support learners who have difficulties with participating in collaborative learning in areas such as self-regulation and emotional self-control, self-motivation, organisation, and goal-setting, and social relationship management. For this reason, it is crucial to train learners to work collaboratively in order to ensure both their engagement and the quality of their contributions (Strauß & Rummel, 2021; Wengrowicz et al., 2018). Incorporating this type of support discreetly and subtly is very important, as learners with non-apparent disabilities tend to hide their condition to avoid stigmatisation or differential treatment (Melián & Meneses, 2022). Promoting metacognition, self-regulation, and problem-solving skills is essential when implementing collaborative learning activities in online higher education (Järvelä et al., 2016; Zapatero et al., 2022). However, according to our findings, these aspects are not currently part of current classroom teaching practice.

Our findings also suggest that social interaction and efforts to engage learners in discussion forums are key to promoting inclusive collaboration. Social interaction has been shown essential to the success of online collaborative learning activities and the inclusion of all learners in the learning process (Gehret et al., 2017). Sánchez-Rojas (2019) found that social interaction in online learning environments seldom occurs spontaneously. In this regard, our participants use several measures to make the learning environment more interactive, although there are still limitations in maintaining group cohesion among learners.

Collaborative learning activities promote closer relationships among learners, which encourages the creation of small communities where learners with disabilities or mental health conditions can interact closely (Reyes et al., 2023). In this regard, both our findings and the previous literature suggest a reciprocal relationship between collaboration and social interaction (Strauß & Rummel, 2021; Zhu & Ergulec, 2023). Thus, these two aspects are complementary. However, to promote equitable participation of all learners in collaborative learning activities, professors should be very careful when choosing media, forms, and formats for interaction and collaboration. Our findings suggest that asynchronous and text-based interaction facilitate the involvement of most learners in collaborative learning. Furthermore, according to Sánchez-Rojas (2019) and Zapatero et al. (2022), asynchronous collaboration encourages reflection and critical thinking, so its adoption is beneficial for all learners.

According to our study, an inclusive collaborative learning approach requires institutional support for professors and the provision of appropriate knowledge, resources, and tools. For instance, in terms of accessibility, the literature suggests presenting and implementing learning activities in multiple formats (Rao et al., 2021), but such a measure is seldom considered when it comes to peer partnership. Collaboration tools, group integration, and activity types also need to be flexible enough to encourage the participation of all learners (Reyes et al., 2023). In this regard, institutions should ensure that collaboration tools are functional and provide sufficient resources for professors to fulfil their responsibilities properly.

Limitations, implications, and future lines of research

The aim of our research was to explore the perceptions of online professors with teaching responsibilities across multiple disciplines at the bachelor's degree level. As we focused on an in-depth analysis of the participants' different experiences to understand their insights, our findings are not representative. It is therefore necessary to carry out further research in this area, using a mixed-methods approach to gain a broader understanding of the phenomenon. It is also important to bear in mind that our findings are based on a particular educational model that focuses on asynchronous interaction. Although our findings are generalisable in the sense that they can be transferred to other learning environments (Braun et al., 2015), other contexts in which synchrony and asynchrony, as well as online and face-to-face interaction, are combined need to be explored to determine their prevalence.

The benefits of online learning, such as time flexibility and reduced commuting, are attractive to many learners with disabilities. Interestingly, although their presence in online higher education has increased in recent years, these groups of learners remain invisible to both institutions and professors. Hearing what they have to say about the role of collaboration in their learning and the impact of participating in this dynamic would be of great value in understanding their experiences. Such a study would shed light on their needs, expectations, and perceptions, and allow implications to be identified to guide the designers of collaborative learning environments, tools, and pedagogical practices in promoting the inclusion of these learners.

Our findings give pause for thought on the role of professors as enablers of learners with disabilities' involvement in collaborative knowledge building. Likewise, our study may serve as a basis for future research aimed at explaining the complexities of online collaborative learning based on inclusive pedagogy. In terms of practice, the results of this research suggest new lines of work applicable to diverse learning environments, whether fully online or blended. Making collaborative learning environments and tools accessible, preparing learners for collaborative work, promoting social interaction in the classroom, and supporting learners emotionally and in self-regulation are crucial aspects for inclusive collaborative learning. Finally, measures aimed at promoting the equitable participation of all learners in collaborative learning should be the result of carefully developed strategies involving the whole institutional structure.

CONCLUSIONS

The end goal of collaborative learning is to involve all learners in collaborative knowledge building and problem solving, which is why it is so important to make it inclusive. Without inclusion, collaboration is not possible. Implementing this approach in a fully online and asynchronous learning environment involves a significant duality. Asynchronous interaction makes it easier to overcome social and accessibility barriers. However, it also tends to discourage affective relationships among learners – an essential aspect in promoting their involvement in collaborative knowledge building. Strengthening learners' affective competencies, making work dynamics flexible, and diversifying collaboration media are crucial to address this ambivalence and to enable a balance between comfort and effectiveness in online collaborative learning.

Professors' interventions to promote the equitable involvement of learners with disabilities in online collaborative learning activities are crucial. They are particularly concerned about the inclusion of learners with sensory difficulties, neurocognitive and neurodevelopmental disorders, and mental health conditions. However, they perceive a lack of appropriate knowledge and resources to adequately address these challenges. Therefore, preparing, sensitising, and supporting professors and providing them with accessible tools and resources for all learners is the first compelling step towards making online collaborative learning inclusive. Enhancing professors' ability to embrace and mediate learners' activities would allow for an effective implementation of collaborative learning in online learning environments, thus promoting the inclusion of all learners.

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Key factors for the success of online collaborative learning in higher education: student's perceptions

Factores clave para el éxito del aprendizaje colaborativo en línea en la educación superior: percepciones del alumnado

Pablo-César Muñoz-Carril - *Universidad de Santiago de Compostela, USC (Spain)*
Nuria Hernández-Sellés - *Centro Superior de Estudios Universitarios La Salle (Spain)*
Mercedes González-Sanmamed - *Universidad de A Coruña, UDC (Spain)*

ABSTRACT

Online collaborative learning (CSCL) has expanded considerably following the restrictions imposed during the pandemic, leading to a need to analyse its foundations and the conditions that affect how well it is delivered. The aim of this study was to develop a model in order to analyse the key factors affecting purposeful online collaborative learning. The participants in the study were 799 students in higher education who had experienced this type of methodology. A questionnaire was created, organized into 7 constructs. This was used to produce a research model with reflective variables using the Partial Least Squares (PLS) technique, which demonstrated good predictive ability (R^2=0.712). The 10 hypotheses underpinning the model were confirmed. The results indicate that variables such as satisfaction, perceptions of use and enjoyment, and group dynamics had a significant, positive influence on students' perceptions of online collaborative learning. Mediating variables of interest were also identified, such as intra-group emotional support (R^2=0.595)—with its link to perceived enjoyment—and the importance of online tools and group dynamics as fundamental elements for developing proper emotional support within the framework of CSCL processes. Finally, the results are discussed, along with their impact on improving teaching in higher education when implementing CSCL.

Keywords: collaborative learning; higher education; university students; distance education; partial least squares; group interactions.

RESUMEN

El aprendizaje colaborativo en línea (CSCL) ha experimentado un impulso considerable después de las restricciones sufridas durante la pandemia y, por ello, es necesario analizar su fundamentación y las condiciones que inciden en su óptimo desarrollo. El propósito de este estudio ha consistido en elaborar un modelo a través del que se analizan los factores clave que inciden en el desarrollo del aprendizaje colaborativo en línea. Participaron 799 estudiantes de educación superior con experiencia en este tipo de metodología. Se empleó un cuestionario, organizado en 7 constructos, a partir del que se generó un modelo de investigación con variables de tipo reflectivo a través de la técnica Partial Least Squares (PLS), obteniéndose una elevada capacidad predictiva (R^2 =0.712). Se confirmaron las 10 hipótesis establecidas que sustentaban el modelo. Se constató que las variables satisfacción, percepción de uso y disfrute, y dinámicas de grupo poseían una influencia positiva y significativa respecto a las percepciones del alumnado sobre el aprendizaje colaborativo en línea. Se identificaron también variables mediadoras de gran interés como es el caso del soporte emocional intra-grupo (R^2 =0.595) y su vinculación con la percepción de alegría y disfrute, así como la importancia de las herramientas en línea y de las dinámicas de grupo como elementos fundamentales para desenvolver, en el seno de los equipos de trabajo, un adecuado apoyo emocional en el marco de procesos de CSCL. Finalmente, se contrastan estos resultados y su incidencia en la mejora de la enseñanza en la educación superior al implementar el CSCL.

Palabras clave: aprendizaje colaborativo; educación superior; estudiantes universitarios; educación a distancia; mínimos cuadrados parciales; dinámicas de grupo.

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INTRODUCTION

The development of individuals, and of social groups, follows a path of self-knowledge and development of the interpersonal skills that are needed for everyday life, and particularly for projects that need cooperation. Because educational processes are based on interaction, thinking of them as part of human socialization systems makes it easier to construct education that is meaningful to its participants, whatever the modality, considering curricular, methodological, and organizational components (Hernández-Sellés et al., 2023). In terms of methodology, and specifically online education, the CSCL model (*Computer Supported Collaborative Learning*)—based on the in-person philosophy of working cooperatively—already has some history in all areas of teaching and types of courses. This is because it can combine the different dimensions of learning: seeking to respond to complex problems; fostering collective creation; and considering socio-emotional and cognitive dimensions. One example of its capacity to articulate learning experiences with a notable social component—something not previously associated with distance learning—is its proliferation during the COVID-19 pandemic, where it was shown to be a useful instrument in an emergency (Frania & Correia, 2022). Nowadays, where technology mediates socialization of knowledge and the drivers for relationships (Ahmed, 2018; Zuboff, 2020), incorporating cooperation skills into CSCL and the social nature of the associated learning makes more sense. It also reinforces other sociocultural educational approaches that have already demonstrated the many advantages of collaboration over more individualist or competitive learning approaches.

CSCL has two objectives: improving learning as opposed to merely individual work, and teaching cooperation, which, as mentioned above, belongs to the realm of relationships ascribed to the reality of being human, and therefore encompasses the professional, educational, and personal spheres (Keramati & Gillies, 2022; Tang et al., 2014). Students themselves have indicated that CSCL improves learning quality by presenting a variety of ideas and perspectives in the process of interaction. It encourages restructuring prior knowledge and co-creation of common constructs (Borge et al., 2018). For learning to occur, it must be anchored in both cognitive and social components, which involves not only recognition as individuals, but also support of the group in all dimensions (Hernández-Sellés et al., 2019; Näykki et al., 2017). Similarly, the preparation of groups with task-based collaborative experiences can be an effective strategy to enhance collaborative learning in various areas and educational settings, providing opportunities to optimize the teaching and learning process through group interaction (Zambrano et al., 2023).

In any case, and precisely because it incorporates such complex technological, pedagogical, and social elements, CSCL does present challenges that make it difficult to implement. These include the need to establish positive interdependence in working groups, potential conflicts, lack of time for implementation, virtual absenteeism, poor management of the process by the teacher, and technological obstacles (Keramati y Gillies, 2022; Noroozi, 2021). In addition, cooperative learning means some reduction in teachers' abilities to control the process and it needs them to be aware of the potential shock it may cause when implemented in highly competitive social environments (Baloche & Brody, 2017).

Because of that, attitude is one of the most important potential determining factors for the efficacy of technology-mediated educational experiences (Chen & Chang, 2014; Yilmaz & Yilmaz, 2022). Collaborative group members' attitudes have an impact throughout CSCL. There is a risk that these attitudes may produce cognitive or social differences, but paradoxically, it is these same differences—resulting from the variety and diversity of individual contributions—that lead to more significant learning.

Studies looking at students who already have experienced CSCL show that constructs such as satisfaction and perceived usefulness—the latter related to improvement in individual learning thanks to contact with the group—are key factors in explaining their attitudes towards collaborative learning (Alenazy et al., 2019; Bölen, 2020; Cheung & Vogel, 2013; Muñoz-Carril et al., 2021). Satisfaction is also positively correlated with students' motivation and attitudes, and in this regard it is worth emphasizing the need to combine the social and cognitive aspects of the experience (Hernández-Sellés et al., 2019; Molinillo et al., 2018). Students' attitudes, along with their prior knowledge and individual abilities, also affect self-directed learning and how active students are in collaborative processes, particularly their performance and motivation, which contributes to the success or failure of online learning (Lasfeto & Ulfa, 2020, Panadero et al., 2021). Within this framework, authors such as Zimmermann and Schunk (2011) have emphasized the importance of developing self-regulation systems for students in virtual contexts. In this regard, students must be able to set learning goals, monitor their progress, regulate their effort, manage time, maintain intrinsic motivation, and employ effective strategies to improve their competencies.

In addition, students' positive attitudes to CSCL contribute to a more pleasant atmosphere and improved levels of perceived learning. They also have a notable influence on perceived enjoyment (Muñoz-Carril et al., 2020; Muñoz-Carril et al., 2021). Studies related to Social Network Awareness (SNA), examining the ability to perceive the knowledge context and the social framework of a peer network in a learning process, showed that mutual peer awareness improved the quality of communication, and with that, the quality of the experience as a whole (Lin & Tsai, 2016; Lin & Lin, 2019). Teachers' attitudes also have an impact on CSCL, and in fact, studies indicate that their attitudes affect educational experiences, with teachers' beliefs and values being critical factors in professional development and in designing education around change and innovation (Baloche & Brody, 2017; González-Sanmamed et al., 2017).

The attitudes and aspects that influence how CSCL is shaped are fundamental. Learning in CSCL happens when interaction happens, as the product of a group coming together and the exchanges that can be produced, with the support of the teacher. Normally, the interaction suggested in collaborative learning processes involves addressing a complex challenge, demanding a high level of engagement, cooperation, and negotiation. In a competitive, accountable environment such as a university, students usually focus on solutions and answers rather than on the process, which is the real key to learning in CSCL. Students need to feel that they can solve problems without confrontation, but they often lack strategies for emotional management (Frania & Correia, 2022). This is a hurdle, because in order to produce the interaction at a cognitive level, they have to properly manage the social level. Students have reported that an interactive, pleasant, safe environment which incorporates emotional aspects is more motivating and has a positive impact on the collective construction of knowledge and improvement of individual learning. This is why achieving intra-group emotional support is so important (Borge et al., 2018; Hernández-Sellés et al., 2020; Keramati & Gillies, 2022; Näykki et al., 2017). Studies in this regard have indicated that perceived enjoyment, related to perceiving experiences as pleasant, interesting, and enjoyable, is linked to the emotional component (Muñoz-Carril et al., 2021; Yang et al., 2023).

This means that poor socialization between peers in a work group, or even with teachers, will produce gaps in the interaction process and will therefore make academic failure more likely. However, motivation and connection between teachers and their students through satisfying interactions will produce learning communities with a sense of belonging that are resilient and focused on achieving objectives (Hernández-Sellés et al., 2020; Hernández-Sellés, 2021a; Kwon et al. 2014). At the beginning, the teacher must ensure that the process is properly designed, considering the experience as a whole. And throughout the process, they must shepherd the group-formation phase, provide support in cases of conflict, and give good-quality feedback (Kuo et al., 2014; Hernández-Sellés et al., 2020).

In CSCL, technology contributes to learning when it is incorporated into the educational experience in line with curricular, social, and cultural aspects (González-Sanmamed et al., 2020; Näykki et al., 2017). The technology acceptance model (TAM) posits that user acceptance of technologies is directly determined by their behavioural intent. In addition to other variables, perceived ease-of-use and perception of usefulness significantly affect students' attitudes when faced with CSCL and their willingness to use the technology (Bölen, 2020; Lin & Lin, 2019; Muñoz-Carril et al., 2021; Yang et al., 2023). A positive attitude to these tools being used as part of learning experiences, such as CSCL, increases students' perceptions of enjoyment (Muñoz-Carril et al., 2020). Motivation theory also points to the emotional attraction of learning tools, indicating that having an interested attitude may be key to driving the overall success of the experience and perceived enjoyment (Renninger & Hidi, 2016).

Technological media must be chosen after careful study, because that will determine students' interactions in their work groups and the emotional support that is promoted, as well as having a positive, significant influence on perceptions of learning (Hamid et al., 2015, Hernández-Sellés et al., 2019).

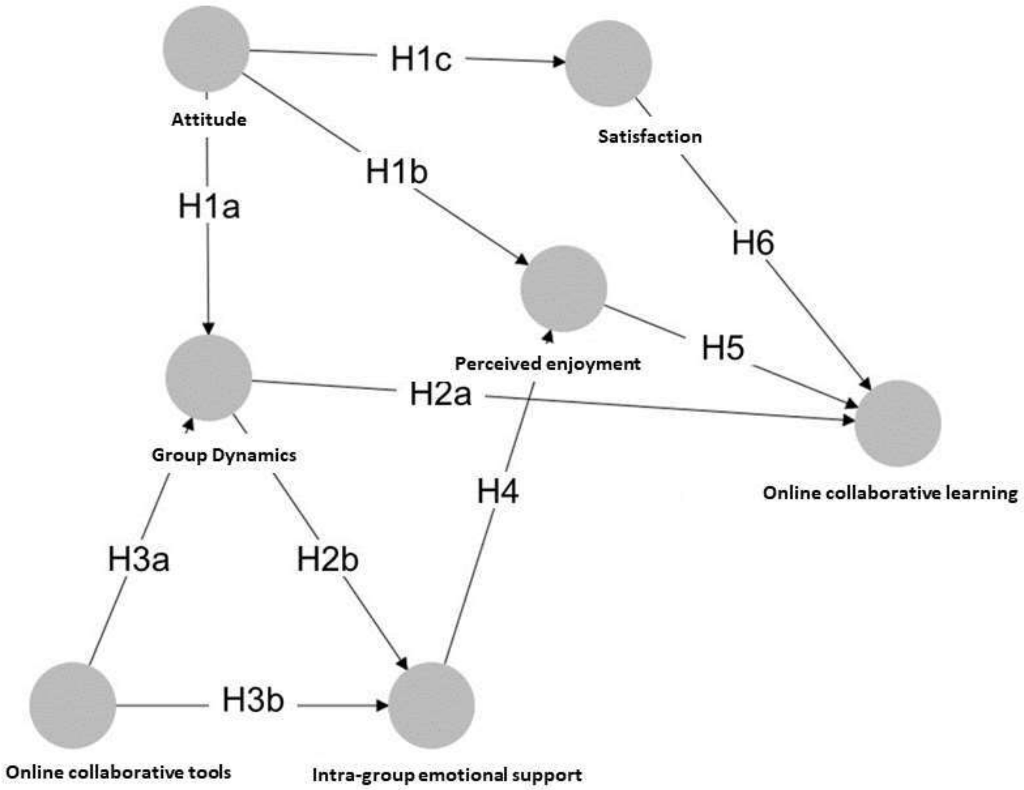
On the other hand, technology also plays a key role in enhancing online collaborative work processes through the use of learning analytics, for example. In this regard, Cerro et al. (2020) demonstrated that the use of these monitoring tools can improve student performance, suggesting that such systems are useful for promoting student collaboration and learning.

Teachers' attitudes towards the tools will also affect the outcome of the experience, and they must not only select the most appropriate means for achieving the learning objectives and meeting student expectations, but must also present the technologies that are going to mediate the accompanying communication, and guide the students to help them make proper use of the tools (Bölen, 2020; Lin & Lin, 2019; Muñoz-Carril et al., 2021; Yang et al., 2023; Yilmaz & Yilmaz, 2022).

RESEARCH MODEL AND HYPOTHESES

Based on the aspects noted above, the general aim of this study was to establish an overall model (Figure 1) that would allow us to determine the key factors affecting collaborative online learning, specifically the factors that would promote better student perception with regard to the learning acquired through CSCL.

Figure 1
Research model



The following hypotheses were formulated:

H1a: Students' attitudes towards online collaborative work (CSCL) will have a significant positive effect on the group dynamics in their work groups.
H1b: Students' attitudes towards online collaborative work (CSCL) will have a significant positive effect on their perceived enjoyment.
H1c: Students' attitudes towards online collaborative work (CSCL) will have a significant positive influence on their levels of satisfaction with collaborative online work (CSCL).
H2a: The dynamics in the collaborative groups will have a significant positive effect on students' perceptions of collaborative learning.
H2b: The interactions in the collaborative groups will positively and significantly influence intra-group emotional support processes.
H3a: The online collaboration tools will have a significant positive influence on work group dynamics.
H3b: The online collaboration tools will positively and significantly contribute to intra-group emotional support in CSCL situations.
H4: The intra-group emotional support within the framework of working collaboratively online (CSCL) will positively and significantly influence students' perceived enjoyment.
H5: Students' perceived enjoyment will have a significant positive effect on their perceptions of learning in collaborative online work (CSCL).
H6: The level of satisfaction shown by the students will have a significant positive effect on the collaborative online learning achieved.

METHOD

Procedure and participants

The study used an *ex post facto* survey-based design (Hernández & Mendoza, 2020). A total of 799 master's degree students took part voluntarily. They were all taking a four-month online subject worth six ECTS credits which involved online collaborative work through project-based methodologies and case studies. Just over half (52.6%) of those surveyed were women, 47.4% were men. The mean age of the participants was 24.7 years old.

With the support and guidance of their teachers, the students were involved in various tasks to understand the implications of CSCL and to learn a variety of strategies that would help them to achieve fluid, effective collaboration. To that end, various sequential phases were implemented during the course: 1) Before the work groups were set up, each student gave a presentation via the virtual campus forum and recorded a video that was published on the class blog; 2) Following the presentations, and before setting up the work groups, an online debate was held based on the content of the course; 3) Collaborative work groups of 4 to 5 members were arranged; 4) Once the groups were established, each team had to discuss and agree key aspects of the group such as the roles and functions each member would have, planning an online calendar with the tasks to carry out during the course, the types of communication tools they would use and to what end, the attitudes they should maintain during the course, protocols for dealing with unexpected events or people dropping out of the group, etc.; 5) Once teachers had reviewed each group's agreements and rules, the groups carried out the various activities required by the course, which were designed according to project-based and case-study methodologies; 6) During the online collaborative work, teachers gave continual feedback and the students had the opportunity for self-evaluation and co-evaluation to consider the results they had achieved.

Once the course was completed, the researchers contacted the students to inform them of the aim of the study, assuring them that their responses would be anonymous and confidential. Data was collected following the course via a self-administered online questionnaire.

Instrument

The data-collection questionnaire used a seven-point Likert-type scale from "completely disagree (1)" to "completely agree (7)". Table 1 shows the means and standard deviations of the 33 items used, spread over 7 constructs. The scale was created using previously validated scales from prior studies on CSCL. For items representing the "attitude" construct, the basis was the scale from Ifinedo (2018). The items for the "group dynamics" construct came from the scale by Ku et al. (2013). The studies by Molinillo et al. (2018) and Hernández-Sellés et al. (2019) were the basis for the indicators of the latent variables "online collaborative tools" and "intra-group emotional support", respectively. The construct "perceived enjoyment" was based on the scale from Martin and Rimm-Kaufman (2015), while the scale used to measure the "satisfaction" construct came from research by Ifinedo (2017). Lastly, the study from Hernández-Sellés et al. (2019) formed the basis for the items in "collaborative online learning".

Before the instrument was applied, it was reviewed by a panel of 5 international experts who examined aspects of each item such as unambiguity, relevance, and importance. A pre-test was also performed to validate the questionnaire with 30 students from the course chosen randomly. Minor grammatical changes were made based on the feedback from the experts and the students.

Table 1

Descriptive statistics for the items making up the constructs in the questionnaire

Construct	Item nº	Description	Mean	Standard deviation
Attitude	ATTI_1	I like learning collaboratively.	5.83	1.42
	ATTI_2	Working in collaboration is a good way to learn.	5.99	1.30
	ATTI_3	For me, doing academic tasks in collaboration is enriching.	5.95	1.29
	ATTI_4	I like the idea of working collaboratively to learn.	5.89	1.38
Group dynamics	SIWOG_01	My group had clear agreements for collaboration to improve the effectiveness of learning as a team.	6.06	1.19
	SIWOG_02	In my group, we trusted each other in order to achieve the course objectives.	5.99	1.35
	SIWOG_03	In my group, all the members were clear about the roles and tasks each one had to do during the collaborative work process.	5.93	1.38
	SIWOG_04	In my group, there were clear goals and agreements for work.	6.18	1.10
	SIWOG_05	The members of my group responded within an appropriate time to issues and comments arising while working in collaboration.	5.82	1.48
	SIWOG_06	The members of my group communicated with each other frequently.	5.98	1.34
	SIWOG_07	I think each member of the group completed their work on time.	5.79	1.59
	SIWOG_08	My group had an effective way of approaching the subject tasks and activities.	5.89	1.39
	SIWOG_09	Communicating regularly with the others in my group helped me to better understand the collaborative tasks to be completed in the subject.	5.99	1.32
	SIWOG_10	Overall, I think there was good cohesion between the members of my group.	6.02	1.43
Online collaborative tools	OCTO_1	The virtual campus tools helped collaboration between the members of the team.	5.60	1.49
	OCTO_2	The team forum allowed for reflection and free-flowing exchange of information.	5.36	1.58
	OCTO_3	Google Suite (Drive, Calendar, Docs...) allowed members of the team to work appropriately on the tasks required by the subject.	6.30	1.05
	OCTO_4	I think that the tools our group used contributed to good communication between the team members.	6.11	1.15
Intra-group emotional support	IGES_1	There were personal links in the collaborative work groups.	4.23	1.90
	IGES_2	Other members of the group offered me support, assistance, and encouragement when I needed it.	5.57	1.52

Construct	Item nº	Description	Mean	Standard deviation
	IGES_3	Working as a team helped me feel more involved in studying this subject.	5.59	1.55
	IGES_4	I feel that the members of my group supported each other mutually throughout the subject.	5.70	1.50
Perceived enjoyment	PENJ_1	Working collaboratively in the virtual environment was fun.	5.15	1.63
	PENJ_2	I enjoyed working in collaboration with the members of my group.	5.42	1.56
	PENJ_3	I liked the feeling of working collaboratively in a virtual environment.	5.56	1.57
Satisfaction	SATI_1	Having completed the course, I'm satisfied with working collaboratively online as a learning method.	5.90	1.34
	SATI_2	I'm satisfied with the methodology of working collaboratively online used in the course.	5.86	1.35
	SATI_3	I'm very happy with the experience of having worked collaboratively in a virtual environment during the course.	5.57	1.56
	SATI_4	I'm satisfied with the level of skills acquired during the course thanks to working collaboratively online.	5.82	1.31
Online collaborative learning	OCL_1	I learned more by interacting with the group than I would have working alone.	5.52	1.63
	OCL_2	Working in a team let me complement my knowledge with that of my team-mates'.	5.79	1.47
	OCL_3	Interacting with the others in my group improved on the marks I would have got working individually in the various course tasks and activities.	5.24	1.70
	OCL_4	Contact with the group helped me to complete my studies.	5.10	1.89

ANALYSIS AND RESULTS

To evaluate the suggested research model, and to test the study hypotheses, we performed multivariate analysis using structural equation modelling (SEM) using the partial least squares (PLS) technique (Hair et al., 2021), which is particularly suited to educational research (see, for example: Cabero-Almenara et al., 2022; Chahal & Rani, 2022; Hair & Alamer, 2022; Hung-Ming et al., 2020; Wang et al., 2023). The analysis was done in two phases, by developing a measurement model and a structural model, using SmartPLS version 4.0.9.6 (Ringle et al., 2022).

Measurement model

As Table 2 shows, adequate values were obtained for reliability and convergent validity. Cronbach's alpha coefficient was greater than 0.81 in all cases. In addition, the indices of composite reliability were well above 0.5 (Bagozzi & Yi, 1989), confirming the internal reliability of each construct. In terms of convergent validity, the average variance extracted (AVE) was well over the minimum required value of 0.5 recommended by Hair et al. (2011), indicating that more than 50% of the variance of each construct is due to its indicators.

The criteria from Hair et al. (2019) was followed for the level of acceptance for factor loading, indicating that values must be above 0.708. As Table 2 shows, all of the values were well above this limit. Nonetheless, two indicators were removed from the initial model that did not reach this limit. One belonged to the *group dynamics* construct, "communication between members of my groups was respectful" (0.682). The other was part of the *online collaborative tools* construct, "I think the tools offered by the virtual campus were sufficient for collaborative learning" (0.700).

Table 2
Reliability and convergent validity

	Cronbach alpha	Composite reliability	Average Variance Extracted (AVE)	Loading
Attitude	0.958	0.970	0.889	
ATTI_1				0.937
ATTI_2				0.937
ATTI_3				0.952
ATTI_4				0.944
Group dynamics	0.961	0.966	0.743	
SIWOG_01				0.778
SIWOG_02				0.897
SIWOG_03				0.812
SIWOG_04				0.814
SIWOG_05				0.900
SIWOG_06				0.880
SIWOG_07				0.857
SIWOG_08				0.915
SIWOG_09				0.850
SIWOG_10				0.905
Online collaborative tools	0.818	0.878	0.643	
OCTO_1				0.770
OCTO_2				0.788
OCTO_3				0.780
OCTO_4				0.866
Intra-group emotional support	0.896	0.928	0.766	
IGES_1				0.734
IGES_2				0.919
IGES_3				0.909
IGES_4				0.924
Perceived enjoyment	0.943	0.963	0.898	
PENJ_1				0.938
PENJ_2				0.955
PENJ_3				0.950
Satisfaction	0.957	0.969	0.887	
SATI_1				0.952
SATI_2				0.952
SATI_3				0.938
SATI_4				0.924
Online collaborative learning	0.914	0.939	0.795	
OCL_1				0.926
OCL_2				0.912
OCL_3				0.884
OCL_4				0.843

To verify the suitability of the measurement model, discriminant validity was examined using three complementary methods. The first consisted of determining whether the loading of each indicator on their respective constructs was greater than the cross-loading on other constructs (Hair et al., 2014). This was found to be the case.

Fornell and Larcker's (1981) criterion was also used to verify that the square root of the AVE for each construct was greater than the correlation between this construct and all the others (Table 3).

Table 3

Discriminant validity using the Fornell-Larcker criterion

	1	2	3	4	5	6	7
1. Attitude	**0.943**						
2. Group dynamics	0.473	**0.862**					
3. Online collaborative tools	0.533	0.641	**0.802**				
4. Intra-group emotional support	0.508	0.749	0.628	**0.875**			
5. Perceived enjoyment	0.689	0.703	0.678	0.767	**0.947**		
6. Satisfaction	0.737	0.674	0.720	0.716	0.868	**0.942**	
7. Perceived learning	0.689	0.677	0.617	0.728	0.808	0.807	**0.892**

Note: The square root of the AVE of the construct is in bold.

Finally, the heterotrait-monotrait ratio (HTMT) was examined to determine whether the correlation between two constructs was less than 0.9 (Henseler et al., 2015). This was found to be the case, with values ranging between 0.490 and 0.858.

After verifying the psychometric requirements for reliability and validity, the structural model was specified to test the study hypotheses.

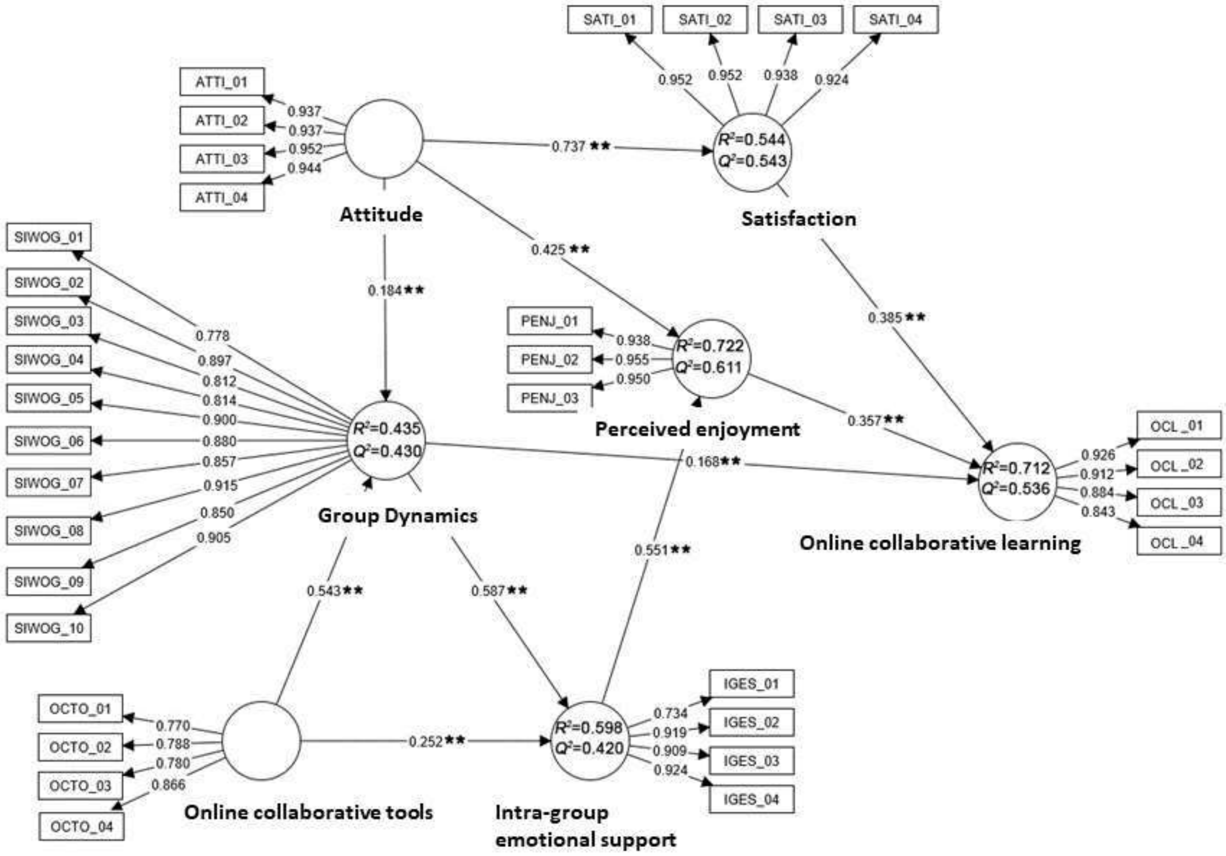
Structural model

Evaluation of the structural model involved analysing the level of significance of the relationships between the constructs along with their predictive quality. Figure 2 gives a graphical representation of the structural model, while Table 4 summarizes the results of testing the study hypotheses.

A bootstrapping procedure with 5000 subsamples (Hair et al., 2011) was used to analyse the robustness of the indicator loadings and to determine whether the relationships between the variables were significant. The R^2 indicator suggests that 71.2% of the variance of the construct "collaborative online learning" was explained by the latent variables "satisfaction", "perceived enjoyment", and "group dynamics" in the model. Based on Chin (1998), which indicates R^2 indices of 0.67 as substantial and 0.33 as moderate. Overall, the predictive value of the model was high.

In addition, the Stone-Geisser or Q^2 test was used to assess the predictive importance of each of the endogenous variables in the model (Figure 2). This gave values in each case above 0.35 (Hair et al., 2022), indicating that the model had a high level of predictive importance.

Figure 2
Evaluation of the structural model via PLS



Note: ** = Significant at p < .001

The results from testing the ten hypotheses (Table 4) show that the model supports all of them. In addition to the standardized regression coefficients (β), Table 4 shows the associated T statistics and the levels of significance (p-value) allowing a determination of whether each hypothesis is supported in the proposed model. The f^2 coefficients were also calculated, as it is not only important to determine whether the relationship between the variables is significant, the size of the effect is also critical (Chin, 1998). The values for f^2 were interpreted using Cohen's (1988) criteria, which establishes values of 0.35 (large), 0.15 (moderate), and 0.02 (small). As Table 4 shows, there were generally large effects in most of the constructs, with the smallest values for f^2 in the relationship between "attitude" and "group dynamics" (f^2= 0.043) and between "group dynamics" and "perceived learning" (f^2= 0.048).

Table 4
Summary of results of hypothesis testing

Hypothesis path	β	T statistic	p-value	f^2	Results
H1a. Attitude → Group dynamics	0.184	4.279	0.000	0.043	Supported
H1b. Attitude → Perceived enjoyment	0.425	13.205	0.000	0.481	Supported
H1c. Attitude → Satisfaction	0.737	30.298	0.000	0.912	Supported
H2a. Group dynamics → Collaborative online learning	0.168	5.099	0.000	0.048	Supported
H2b. Group dynamics → Intra-group emotional support	0.587	16.365	0.000	0.504	Supported
H3a. Online collaborative tools → Group dynamics	0.543	13.947	0.000	0.374	Supported
H3b. Online collaborative tools → Intra-group emotional support	0.252	6.698	0.000	0.093	Supported
H4. Intra-group emotional support → Perceived enjoyment	0.551	18.243	0.000	0.809	Supported
H5. Perceived enjoyment → Online collaborative learning	0.357	6.534	0.000	0.098	Supported
H6. Satisfaction → Online collaborative learning	0.385	7.878	0.000	0.123	Supported

Finally, the goodness-of-fit of the structural model was assessed using the SRMR (*Standardized Root Mean Square Residual*), which gave a result of 0.06, demonstrating a reasonable fit for the model as it was lower than 0.08 (Hu & Bentler, 1999).

DISCUSSION AND CONCLUSIONS

The first point to note is that the model proposed in the study demonstrated good predictive ability (R^2=0.712), and that the ten hypotheses were supported. The results allowed us to identify the factors that affected online collaborative working according to the perceptions of students who had taken part in this type of course. More specifically, there was a significant, positive effect on CSCL from the following factors: *group dynamics* (H2a; β=0.168; p<0.001; f^2=0.048); *satisfaction* (H6; β=0.385; p<0.001; f^2=0.123), and *perceived enjoyment* (H5; β=0.357; p<0.001; f^2=0.098),

The construct concerning *group dynamics* includes the fundamental components that have been shown to be key to the success of collaborative learning: “cognitive presence”, “social presence”, and “teaching presence”. Cognitive presence refers to collaborative construction of learning thanks to intentional collaboration and negotiation, where individual contributions gain collective meaning in symbiosis, and where the combination of divergence and convergence produces satisfactory results (Puntambekar, 2006; Borge et al., 2018). The cognitive aspects cannot be understood without the emotional and motivational aspects, which leads to the need to also consider “social presence”. This looks at the characteristics of the students—their willingness to work towards shared goals, their engagement in the group task, each person’s contributions, and the possibility of encouraging a feeling of community—as elements that allow support and communication (Näykki et al., 2017). In any case, it is important to remember that collaborative learning processes do not happen spontaneously or randomly. They need thorough planning and realistic design in a detailed sequence that ensures appropriate conditions and media. This leads to the need to consider “teaching presence”, and through that, pedagogical, curricular, and technological aspects in each of the phases of planning, interaction, and evaluation (Garrison et al., 1999, Hernández-Sellés et al., 2020).

The other key factor in CSCL is satisfaction, which depends in turn on good planning of the aforementioned components, especially well-structured collaborative processes which combine both cognitive and social development (Kwon et al., 2014; Alenazy et al., 2019; Bölen, 2020). Other factors that help ensure student satisfaction included teacher feedback (Kuo et al., 2014), emotional support between students (Zhan, 2008), and perceived usefulness (Bölen, 2020).

When it comes to *perceived enjoyment*, authors such as Ifinedo (2017) point to a positive assessments of both technology-mediated learning and the collaborative process itself, as well as to the relevance of meeting student's expectations and confirming predicted actions (Park, 2020).

In addition to the three foundational components noted above, it is important to also consider the other components of the model, both for their specific importance and from the kind of overall viewpoint that should be part of both a theoretical analysis (that allows conceptual identification of CSCL) and a pragmatic one (that helps in design and implementation). In this regard, *attitude* is hugely important, because of its notable influence in the three factors that contribute to collaborative online learning: group dynamics (H1a; β=0,184; p<0.001; f^2=0.043), satisfaction (H1b; β=0,425; p<0.001; f^2=0.481), and perceived enjoyment (H1c; β=0,737; p<0.001; f^2=0.912). Positive attitudes are correlated with ease of use and perceived usefulness, and so these aspects need to be considered both before and during CSCL (Hernández-Sellés et al., 2019).

The other fundamental component comes from *technological tools*, without which CSCL would not be possible. In our study, there was a clear influence of digital resources on group dynamics (H3a; β=0,543; p<0.01; f^2=0.374) and on intra-group emotional support (H3b, β=0,252; p<0.01; f^2=0.093). Various studies have shown how important devices are in the synchronous and asynchronous interactions that occur during CSCL (Hamid et al., 2015; Hernández-Sellés, 2021b). Consequently, they play a key role in groups working well together, in relationships with teachers, and in accessing content, providing the necessary infrastructure for learning to be produced and shared (Yang et al., 2023; Yilmaz & Yilmaz, 2022).

It is worth reiterating that interpersonal relationships will help to improve and reinforce interactions, and improve group members' engagement (Molinillo et al., 2018; Voupala et al., 2016), positively influencing *intra-group emotional support* (H2b, β=0,587; p<0.001; f^2=0.504) and ultimately facilitating achievement of significant, active learning. And this intra-group emotional support will significantly and positively influence students' perceived enjoyment, which contributes to effective collaborative learning (H4; β=0.551; p<0.001; f^2=0.809).

Lastly, it is worth noting that the findings from the present study contribute to expanding the theoretical corpus on CSCL. From an operational perspective, the study has confirmed the importance of key factors influencing and contributing to achieving suitable collaborative learning processes, based on the perceptions of students who participated in such activities. This is particularly useful for teachers and institutions who want to implement CSCL-based activities, where pedagogical, cognitive, and emotional aspects must be considered in the design, implementation, and evaluation of each educational activity.

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Teacher scaffolding for knowledge building in the educational research classroom

Andamiaje docente para la construcción del conocimiento en el aula de investigación educativa

Calixto Gutiérrez-Braojos – *Universidad de Granada, UGR (Spain)*
Paula Rodríguez-Chirino – *Universidad de Granada, UGR (Spain)*
Beatriz Pedrosa Vico – *Universidad de Granada, UGR (Spain)*
Sonia Rodríguez Fernández – *Universidad de Granada, UGR (Spain)*

ABSTRACT

Knowledge Building is an educational model characterized by its emphasis on the collective responsibility of students to improve collective ideas. Previous studies have demonstrated the benefits of Knowledge Building in science education. This study implements this pedagogy in the field of educational research and pursues two objectives: i) to analyze the quality level of student contributions when participating in a collaborative space to enhance ideas, and ii) to analyze the scaffolding employed by teachers during the implementation. A mixed-method design (qualitative and quantitative) was employed to collect data. The participants consisted of 59 undergraduate social education students enrolled in an action-research course. Data on the quality of discourse were collected from the entries or notes created by students on the Knowledge Forum platform, while data on teacher scaffolding as perceived by the students was obtained through interviews. The results of this study demonstrate that most student contributions are of high quality, although participation shows a slightly uneven distribution. Furthermore, this study broadens our understanding of the teaching scaffolds that support students' knowledge construction in educational research and offers teaching scaffolds that can be applied in various constructivist learning contexts aimed at promoting student autonomy to collaborate in knowledge creation.

Keywords: teaching; educational innovation; educational research; group learning; educational technology; didactic use of computer.

RESUMEN

La Construcción del Conocimiento es un modelo educativo que se caracteriza por su énfasis en la responsabilidad colectiva de los estudiantes para mejorar las ideas colectivas. Estudios previos han demostrado los beneficios de la Construcción del Conocimiento en la enseñanza de las ciencias. Este estudio implementa esta pedagogía en el campo de la investigación educativa y persigue dos objetivos: i) analizar la calidad de las contribuciones de los estudiantes al participar en un entorno colaborativo para mejorar las ideas, y ii) examinar los andamios utilizados por los docentes durante la implementación. Se utilizó un diseño de investigación mixta que incluyó enfoques cualitativos y cuantitativos para recopilar datos. Los participantes fueron 59 estudiantes del grado de educación social inscritos en un curso de investigación-acción. Los datos sobre la calidad del discurso se recopilaron a partir de las entradas o notas elaboradas por los estudiantes en la plataforma Foro del Conocimiento, mientras que los datos sobre los andamios docentes, tal como los percibieron los estudiantes, se obtuvieron a través de entrevistas. Los resultados de este estudio revelan que la mayoría de las contribuciones del alumnado son de alta calidad, aunque se observa una distribución ligeramente desigual en la participación. Además, este estudio amplía nuestra comprensión de los andamios de enseñanza que respaldan la construcción del conocimiento del alumnado en materia de investigación educativa, y ofrece andamios docentes que pueden aplicarse en diversos contextos de aprendizaje constructivista que persigan fomentar la autonomía del alumnado para colaborar en la creación de conocimiento.

Palabras clave: enseñanza; innovación educativa; investigación educativa; aprendizaje en grupo; tecnología de la educación; aprendizaje asistido por ordenador.

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INTRODUCTION

Nowadays, Social Constructivism is widely recognized and accepted as an educational theory. Social constructivism emphasizes the social nature of cognition and advocates for creating communities of learners who collaborate to achieve better outcomes in their learning (McLeod, 2019). From a Social Constructivist perspective, the collaborative learning approach argues that knowledge is less an individual possession and more a collective good. This knowledge is constructed by members of a group through participation in shared activities, and the exchange of ideas and resources (Yang, Zhu et al., 2022). In other words, collaborative learning involves an active process in which learners construct their understanding by taking advantage of their interactions with their environment and with other learners (Stahl, 2020). This approach focuses on designing and implementing educational environments that promote meaningful interactions among students, facilitating the appropriation of the knowledge construction process in a collaborative and personal way (Rannikmäe et al., 2020).

In recent years, lines of educational research based on technological innovations have been developed in alignment with the socio-constructivist perspective (Fernández-Miranda et al., 2022; Palacios-Ortega et al., 2022). Computer-supported collaborative learning (CSCL) focuses on the design and implementation of technology to support collaborative learning by facilitating learning processes and the sharing or co-construction of knowledge (Chen et al., 2018; Radkowitsch et al., 2020). Within the field of CSCL, many educators actively strive to create effective educational environments that promote collaboration among students and facilitate the development of shared understandings on complex knowledge issues (Zhang et al., 2020). These environments are designed to encourage the exchange and discussion of ideas, providing tools that facilitate cognitive and social interaction with the aim of achieving a deeper level of understanding (Schnaubert & Vogel, 2022). Teachers who prioritize student autonomy in learning for problem-solving recognize that CSCL is suitable for achieving these goals (McKeown et al., 2017). In CSCL environments, students demonstrate higher levels of learning, make higher-quality decisions, complete more thorough tasks, engage more equitably in the learning process, and experience greater satisfaction compared to those following more traditional educational approaches (Järvelä et al., 2020). These learning environments capitalize on peer collaboration, supported by technological tools, to monitor, assess, and enhance both collective and individual knowledge (Stahl et al., 2006). Furthermore, it is widely acknowledged that social interactions and collaborative efforts play a crucial role in the learning process, influencing the overall quality of the achieved outcomes (e.g., Järvelä et al., 2023). Extensive empirical studies and meta-analyses have widely reported the positive effects of computer-supported collaborative learning on students' learning outcomes and processes (e.g., Chen et al., 2019).

The work of Scardamalia and Bereiter (1996) is pioneering in the field of CSCL. They introduced the educational model called “Knowledge Building”, which involves students in the collaborative advancement of knowledge. Research on Knowledge Building (KB) has seen a significant increase in recent years (Gutiérrez-Braojos et al., 2020), with a substantial emphasis on the design and development of technologies and educational scenarios that facilitate student communities in collaboratively constructing their knowledge and assuming responsibilities (Stahl & Hakkarainen, 2021). This study investigates the effects of Knowledge Building on novice students

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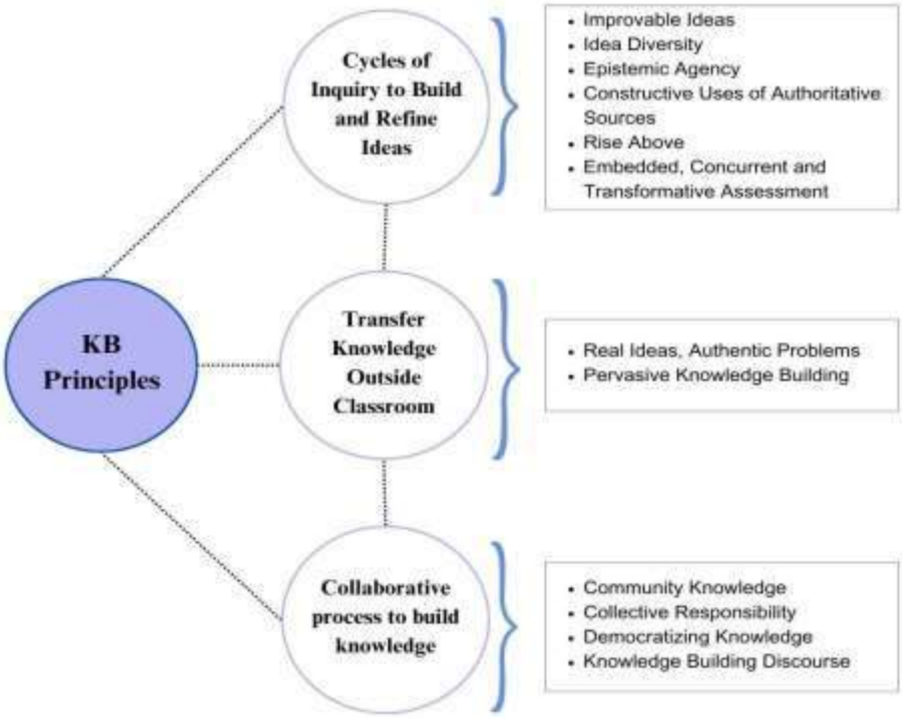
with limited knowledge of educational research. The subject of Educational Research presents a certain level of complexity. When students attempt to learn this subject, they often encounter comprehension difficulties (Gussen et al., 2023). There is evidence that an active and collaborative pedagogical proposal is efficient to teach science and research skills (Jiao et al., 2011; Vandiver & Walsh, 2010), but there are not so many studies carried out from the Knowledge Building pedagogy to teach research methods (Gutiérrez-Braojos et al., 2022). This study explores whether the socio-constructivist educational model Knowledge Building, based on collaboration among students to exchange and enhance collective ideas, fosters learning in the field of educational research.

An Educational Model for the 21st Century: Knowledge Building

In an era where information is readily accessible, Knowledge Building emerges as an educational model that fosters a culture of collaborative knowledge creation in educational environments (Scardamalia & Bereiter, 2021). Knowledge Building is inspired by Popper's theory of Objective Knowledge (Popper, 1972). This theory suggests considering three interconnected worlds to understand knowledge. 'World 1' is the physical world, 'World 2' is the realm of conscious experiences or subjective knowledge, and 'World 3' is the world of autonomous logical content products of the human intellect, such as that available in computers, libraries, etc. Knowledge Building is a model that transcends individual learning within 'World 2,' with the goal of enabling communities of learners to construct and refine shared knowledge in 'World 3,' much like communities and teams of scientists. It represents a promising educational model to developing students' competencies and skills needed to succeed in the 21st century (Tan et al., 2021). Knowledge Building has proven effective in empowering students, enabling them not only to acquire knowledge, but also to learn to collaboratively inquire, develop and refine ideas supported by reliable sources to solve real problems, and to take shared responsibility for cognoscitive advancement (Bereiter & Scardamalia, 2016).

Knowledge Building can be implemented across various educational contexts and disciplines[1], particularly in those related to the sciences. This is an educational model that effectively complements other educational innovations, such as in the field of robotics learning (e.g., Khanlari, 2019). The implementation of Knowledge Building in the classroom requires teachers to design an educational environment based on 12 principles (Scardamalia, 2002) (Figure 1). This environment facilitates opportunities for students to share, question, debate ideas, and develop new skills with the purpose of constructing and refining their knowledge about authentic problems (Ma & Scardamalia, 2022). This implies that teachers must progressively delegate responsibilities related to knowledge construction to students. To do this, teachers should provide various types of scaffolding to facilitate students during the Knowledge Building implementation. Scaffolding is a concept with its origins in sociocultural theory (Vygotsky, 1978). It refers to the process in which students have adaptive support tailored to their progress needs (Svendsen & Burner, 2023), while scaffolds are tools that provide support to complete a specific zone of proximal development (Puntambekar et al., 2021; Van de Pol et al., 2019).

Figure 1
Figure of the principles



In educational literature, there are various scaffolding proposals specifically designed to support students in meeting the challenges presented by a constructivist-based learning environment. For example, Finelli and Borrego (2020) suggest three ways to support students: planning the learning environment and conditions, identifying when students need explanations about the content or activities, and providing students with opportunities to achieve learning. Other proposals, such as that of Zhu and Lin (2023), focus on introducing scaffolding strategies to encourage students to collaborate in discussions and enhance their knowledge, such as: i) initiate an inquiry; ii) encourage students to elaborate on/deepen their ideas, iii) encourage students to build on ideas contributed by community members; iv) encourage new ideas or new inquiry directions; v) establish community norms; vi) direct instructions/guidance. In other words, teachers act as guides and mentors, providing guidance, feedback, as well as timely support, when necessary, to ensure that students engage and collaborate effectively to enhance their ideas.

Knowledge Forum: Technology for Collaborative Knowledge Building

Recognizing the significance of technological advancements to build knowledge (Popper´s three worlds), Knowledge Building has placed substantial emphasis on the educational innovation with technology (Khanlari et al., 2019; Tan et al., 2021). Knowledge Forum (KF) (Scardamalia, 2004) is a technological platform specifically designed to support Knowledge Building implementation in the classroom. This platform offers a structured environment that streamlines the development of crucial collaborative idea construction processes, including expressing ideas, building upon the contributions of others, critically evaluating information, and engaging in meaningful discussions (Laferrière & Lamon, 2010). Through its features, Knowledge Forum empowers participants to connect their ideas, explore diverse perspectives, and collectively foster a deeper comprehension of intricate concepts (Soliman et al., 2021).

Knowledge Forum offers a range of tools and functionalities that empower learners in their knowledge-building endeavors (see Figure 2). For instance, it allows students to generate and share their own contributions, nurturing a sense of ownership and agency in the learning process (Hong & Scardamalia, 2014). The platform also enables the organization and visualization of ideas, making it easier to organize their contributions (Bereiter & Scardamalia, 2016). Students using Knowledge Forum engage in online interactions employing various scaffolds to enhance collective knowledge, including posing questions, presenting proposals, offering explanations, and generating research (Gutiérrez-Braojos et al., 2018). Studies that have examined discourse through different categorization schemes have found that most students significantly contribute to the advancement and refinement of collective knowledge on the Knowledge Forum platform, while demonstrating a strong mastery of that knowledge (Cacciamani et al., 2021; Soliman et al., 2021; Yang, Zhu et al., 2022; Zheng et al., 2021).

Figure 2
Knowledge Forum Platform

The idea that students should assume that the responsibility for advancing knowledge is distributed among all members is a key pillar of Knowledge Building (Scardamalia, 2002). Knowledge Building is not an individual and isolated process but is enriched when the contributions and perspectives of all participants are valued and integrated. When students take on this shared responsibility, a sense of community and collaboration is fostered. In other words, students recognize that the responsibility for learning doesn't rest solely with the teacher or a handful of standout individuals. Instead, students understand that every member can provide a valuable contribution to the collective knowledge. This idea promotes equity and inclusion in learning, as it values the diversity of experiences, knowledge, and skills of all participants. In this line, Knowledge Forum provides opportunities for students to receive feedback from their peers and educators, fostering a culture of constructive criticism and continuous improvement (Tarchi et al., 2013). This dynamic is made possible thanks to the continuous improvements of the Knowledge Forum platform itself, as well as the creation of new technologies associated with Knowledge Forum, ensuring it remains at the forefront of educational technology. Some of these advancements are evident in the software's analytics capabilities, which provide teachers and students with tools for conducting concurrent and reflective assessments (Gutiérrez-Braojos et al., 2023; Teo & Tan, 2023, Yang, Zhu et al., 2022). Therefore, these technological innovations associated with Knowledge Forum facilitate a more responsive and insightful education.

The challenge of teaching in the subject of Educational Research

Higher education aims to train students who can address the complex challenges of contemporary society, overcoming limitations of thinking not supported by evidence (Murtonen & Salmento, 2019). Scientific reasoning and skills training are present, to a greater or lesser extent, in most education study programs worldwide (Gess et al., 2018). Pre-service educators should have a solid understanding of the discipline they are pursuing as professionals and engage in scientific inquiry to promote innovation in professional contexts (Ciraso-Calí et al., 2022). This will enable them to generate valuable knowledge and enhance their professional praxis. Scientific competence requires students to develop associated skills such as formulating questions, making conjectures, planning research, analyzing data, drawing conclusions, and practical implications (Bottcher & Thiel, 2018; Khan & Krell, 2019). However, recent studies claim that students who take courses in research methods often encounter many difficulties related to reasoning and scientific skills in the educational field, for example, collecting and analyzing data (Earley, 2014). In fact, students often perceive the research subject as uninteresting and irrelevant to their future careers, as well as challenging due to its difficulty (Nind et al., 2020). And therefore, students often show a passive or negative attitude towards learning educational research knowledge and skills (Gussen et al., 2023; Murtoten, 2015).

Schutt et al., (1984), (cited in Earley, 2014) recall the complexity associated with learning about research methods when they state that research is a “sustained task that involves a number of different kinds of activities that must be interrelated carefully and for which decisions made at one state of the process influence choices at later ones” (p. 242). In instances where the subject matter is particularly intricate, students may face challenges due to the intrinsic cognitive overload and lack of sufficient prior knowledge (Sweller et al., 2019) within the allocated time. Intrinsic load refers to the inherent complexity of a learning task, and this complexity is influenced by the interaction between the task elements and the student's prior knowledge (Liu et al., 2022). Element interactivity pertains to the combination of the number of elements to be learned and the number of interactions between each of these elements. The connection between intrinsic load and the student's prior knowledge lies in the fact that prior knowledge typically assists the students in reducing the interactivity of the elements (Endres et al., 2023). Moreover, there is a possibility that some students may become overwhelmed by the confusion, leading to frustration, and ultimately, complete disengagement from the learning process (Chevrier et al., 2019; Pekrun et al., 2014), making it necessary to provide additional guidance and support (Finelli & Borrego, 2020; Madison et al., 2022; Tharayil et al., 2018)

The current study

In this study, we conjecture that socioconstructivist educational approaches, which encourage students to share and refine their ideas and questions rather than keeping them to themselves, promote the improvement of knowledge at both the individual and collective levels (Stahl & Hakkarainen, 2021). Secondary studies have consistently shown positive outcomes in most of the Knowledge Building implementations, where students improve their collaborative skills and contribute to collective knowledge, while acquiring new knowledge (e.g., Chen & Hong, 2016). In fact, some of these effective implementations carried out through Knowledge Building have been in subjects related to reasoning and scientific skills (e.g. Gutiérrez-Braojos et al., 2022). In addition, there are very few studies that have explored teacher scaffolds to provide support to students while they improve and refine their ideas (Zhu & Lin, 2023).

In this study, we aim to assess the effectiveness of Knowledge Building in teaching all students in the field of educational research, as well as identify the teaching scaffolds perceived by students during the implementation of Knowledge Building. Specifically, this study aims to address the following research questions:

- (Q1) What are the overall effects and impacts of implementing Knowledge Building pedagogy in educational research?
    - (Q1.1) To what extent is the responsibility distributed among students to participate in a collaborative space to enhance collective knowledge?
    - (Q1.2) What levels of learning are reflected in individual contributions made by students in the Knowledge Forum?
    - (Q1.3) What student profiles are identified based on their contributions to the online platform?
- (Q2) What teaching scaffolds are positively perceived by learners in promoting collaboration among students and enhancing understanding of the subject?

METHODS AND MATERIAL

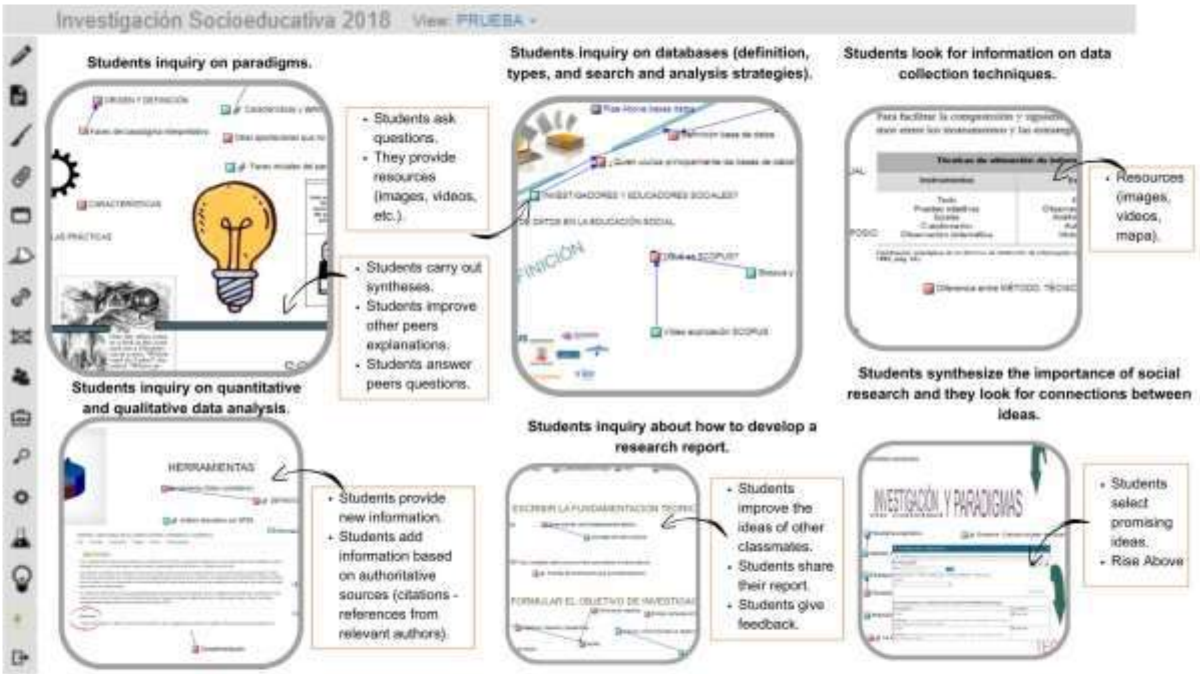
To address the research questions in this study, we employed a mixed-method design (Creswell & Guetterman, 2021). Johnson et al. (2007) refer to mixed methods research as that “in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., the use of and viewpoints on quantitative data collection, analysis, inference techniques) for the general purposes of breadth and depth, understanding, and corroboration" (p. 124). In this study, we addressed different threads to answer the questions posed, and with all of them, to understand the effects generated by the implementation of Knowledge Building, and the teaching scaffolds that support an effective implementation.

Participants and Course Environment

A total of 59 students were included in the sample of this study, all of whom were enrolled in a 16-week course focused on educational research where the Knowledge Building pedagogy was implemented. The course was facilitated through the Knowledge Forum platform (Figure 3). On average, participants dedicated approximately 3 hours per week to actively participating in the course activities in a hybrid environment, i.e., those environments in which “se difuminan las fronteras entre las actividades en línea y presenciales dando continuidad a los aprendizajes [the boundaries between online and face-to-face activities blur, providing continuity to learning]” (Coll et al., 2023, p. 11).

Figure 3

Moves to improve Knowledge about Educational Research Classroom



Students followed the work inquiry cycles described below to achieve the proposed knowledge objectives:

- Questions: students identify the questions they want to address and the aspects they would like to explore regarding a topic identified in the syllabus of the subject. These questions are distributed among small working groups.
- Information retrieval: students conduct thorough inquiry to answer the posed questions. They use both the materials provided by the instructor and different bibliographic databases to gather relevant data and academic sources.
- Individual and collective responses: the students develop their responses individually or collectively, then share and discuss their findings on the Knowledge Forum. This digital platform is designed to facilitate remote communication, collaboration, and the constructive work of ideas. Moreover, the platform records all the ideas generated by the community during the knowledge building process.

- Idea presentation: in class, students present the ideas registered on the Knowledge Forum platform, generating a debate around them. This exchange fosters reflection and collective and individual knowledge building, delving deeper into the topics addressed and generating new insights.
- Evaluation session: both the instructor and the students participate in an evaluation session. The teacher provides an assessment of the work in the Knowledge Forum, identifies possible errors, and suggests improvements.
- Formulating new questions: based on the feedback and reflections arising during the process, new questions are formulated to guide the subsequent phase of inquiry and knowledge building.

At the end of the course, students worked in small groups and selected valuable ideas related to the discussed topics. These were captured into concise texts and visual representations, which served the purpose of organizing and connecting ideas to foster a holistic understanding. These summarized representations enable quick access to key concepts of the course and promote deep understanding, connections between ideas, and effective communication of knowledge among course participants.

Data collection and analysis procedures

The data obtained from the Knowledge Forum records have been analyzed using Rstudio through four phases:

Firstly, an analysis of the registered participation in the Knowledge Forum platform was conducted. To assess the level of participation, the number of notes created by each student was quantified, and the GINI index was calculated. Gini coefficient, the Lorenz Curve, and derivative indices have been used in previous Knowledge Building studies (e.g., Gutiérrez-Braojos et al., 2018; Gutiérrez-Braojos et al., 2022), computer-supported collaborative learning (e.g., Chen et al., 2024; Slof et al., 2020; Strauß & Rummel, 2021; Tucker et al., 2020), and also in centimetric studies to analyze the equitable distribution of authorship (e.g. Salgado-Orellana et al., 2021), and collaboration in science (e.g., Rousseau et al., 2023). Additionally, a Lorenz curve was plotted to show the cumulative percentage of grades corresponding to the cumulative percentage of students in the community, accompanied by a descriptive polar graph of each student's participation.

Secondly, a content analysis of the contributions made by students in the Knowledge Forum was conducted using the SOLO taxonomy (initial coding phase matching 89%, authors reached complete agreement). The categorization system based on the Structure of the Observed Learning Outcome (SOLO) taxonomy (Biggs, 2011) was used in previous Knowledge Building (e.g., Chan et al., 2002; Schrire, 2006; Tammeleht, 2022, Gutiérrez-Braojos et al., 2022) and CSCL studies (e.g., Cai & Gu, 2022). SOLO taxonomy provides a structured framework with five levels of complexity, categorized into two levels, the surface level, and the deep level (Lister et al., 2006):

- The surface level includes pre-structural, unistructural, and multistructural contributions, which provide relevant elements but may be disconnected or disorganized:

- Pre-structural level: This is the least sophisticated type of response; irrelevant elements are used, and necessary elements are omitted.
- Unistructural level: This response reflects a partial understanding of the problem, with some aspects correctly understood but others still missing.
- Multistructural level: This is a response where the student demonstrates comprehension of relevant components of the problem but is not aware of the interrelationships among them.

- The deep level includes relational level and/or extended abstract level:

  - Relational level: The student organizes the different components of the problem into a structure and uses that structure to successfully solve the question.
  - Extended abstract level: This is the most sophisticated type of response. Student's response surpasses the immediate question and establishes connections between the problem and a wider context.

Other contributions made for different reasons (e.g., community functioning, expressing gratitude, etc.) were omitted from this study. In the initial coding phase, the data were encoded by two authors with previous experience in the SOLO taxonomy (adding a third party in case of disagreement). This analytical strategy has been used in other studies as well (e.g., Holmes, 2005; Schrire, 2006). Subsequently, a descriptive analysis was conducted, and two graphs were created: a box plot illustrating the mean, median, and distribution of grades, and a polar graph showing the number of surface and deep grades for each student.

In the third phase, learners' profiles were analyzed according to their contributions on the online platform. Since the polar graphs seemed to indicate two groups of students, a robust cluster analysis using the K-medoids algorithm with PAM (which is not affected by outliers) was performed, resulting in two student clusters. Finally, significant differences between these clusters were tested, and effect sizes were calculated.

In the fourth phase, a content analysis of interviews with 10 graduate students was carried out. The purpose of this analysis was to identify the scaffolds that were implemented by the teachers and were perceived positively by students to promote collaboration among students and improve their understanding of the subject. Students were selected according to their level of achievement in the course to ensure the collection of a broader range of perspectives (3 students with a low level, 4 students with medium levels, and 3 students with a high level). The students participated in an extensive interview about their experience on the course. However, in this study, we only present the results of the questions used to collect data related to the scaffolding provided by the teachers: How was your learning experience in Knowledge Building? Have you faced any challenges or difficulties when collaborating with your peers to improve collective knowledge? What factors have helped you the most in collaborating with your peers to enhance collective knowledge? Have you noticed any teacher-provided assistance that is valuable for the community? The coding scheme proposed is based on the proposal of Finelli and Borrego (2020), Tharayil et al. (2018) and Zhu and Lin (2023) about scaffolds teaching to promote active learning. The data have been jointly coded by 2 authors. They separately analyzed the text to identify segments in which certain conditions occurred under which teachers provided support according to the students. Later, they coded and categorized these conditions according to the following categories and reached complete agreement.

- The category "Planning" corresponds to the teacher's scaffolds for preparing the implementation of KB in the subject.

  - Support to establish knowledge directions and trajectory: the teacher and students build together (teacher and whole class) a map of big questions/goals considering prior knowledge and what is expected in the subject.
  - Support students by providing authoritative sources: the teacher provides specialized literature to prevent students from feeling lost to afford questions.
  - Supporting students by providing technologies for collaborative work: the teacher provides the Knowledge Forum tool, which is in line with the principles of Knowledge Building.
  - Support students by providing a sequence of inquiry: the teacher establishes heuristic to improve collective ideas (i.e., cycle of steps to inquiry and advancement of knowledge).

- The category 'Explanation' refers to the introduction, clarification, and description of issues related to cognitive difficulties that arise during the knowledge building process.

  - Support students in understanding what is expected from them in KB pedagogy: the teacher assists students who have difficulties to understand what is expected to fulfill with KB principles.
  - Support students in understanding how to use KF platform: the teacher assists students who have difficulties using certain tools in the Knowledge Forum.
  - Support students to write notes on KF according to science criteria: the teacher explains and provides examples of what constitutes a well-written note versus a poorly written one in the KF (take time to look information and reflect about it, clarity, conciseness, evidence-based, and the use of keywords; look for evidence to corroborate or counter-argue a peer's idea; take time to write and revise a note, including citation and references).
  - Support students to do good discourses moves to build on issues shared on community according to KB principles: the teacher explains and provides examples of how to contribute and refine collective knowledge (for example, elaborating analogies to explain ideas, looking for new perspectives, carrying out synthesis of their ideas), and what discourse moves are not appropriated (for example, repeating peers' ideas).
  - Supporting students who require additional assistance to understand complex concepts for them: the teacher identifies misconceptions or encounters difficulties in understanding complex concepts during discussions within larger groups or by requesting feedback from students about epistemic emotions (e.g., confusion) The teacher explains why students are confused about these issues, suggests actions to clarify doubts, or asks questions to facilitate deeper understanding.

- The category "Facilitation" refers to teaching scaffolds aimed at ensuring student engagement throughout the implementation of the goals until their completion.
    - Provides opportunities and encourages students to stay updated on shared ideas on the platform: the teacher allocates time and motivates students to critically read their peers' contributions and select promising ideas.
    - Provides opportunities and encourages students to take ideas from the Knowledge Forum and expand upon them: the teacher provides time and motivates students to correct or improve their peers' ideas or propose new ones.
    - Provides opportunities and encourages students to challenge themselves with knowledge: the teacher poses challenging questions to enhance platform ideas/perceptions.
    - Provides opportunities and encourages students to participate in the platform/class discussion: when participation is improvable (either collectively or individually), the teacher informs about the current state of participation, encourages, and allocates time for students to participate in the Knowledge Forum or in-person discussions each week.
    - Provides opportunities and encourages students to become more autonomous working with platform ideas: the teacher motivates students to take initiative in the community (reducing teacher support as the course progresses).
    - Provides opportunities and encourages students to maintain a democratic environment in the community: the teacher encourages students to respect democratic norms when participating in online discussions or class (taking turns to speak, tolerance for other opinions or diversity of ideas, helping others when requested, etc.).

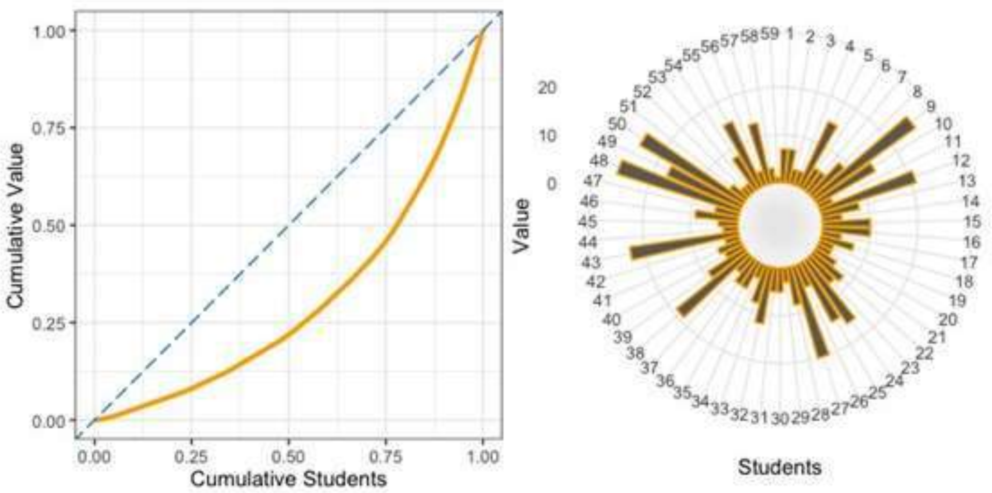
RESULTS

Result 1: Equidistribution of participation

The students made a total of 506 individual contributions ($\bar{x}$=8.58, Sd=6.64), of which 5.14% were classified as "community functioning" and the rest as "contributions to the improving of community knowledge". The Gini coefficient value (G = .39) indicates a slight inequality in the distribution of grades among the students.

The Lorenz curve graph shows clear leadership in terms of participation, as 75% of the students have made slightly less than 50% of the contributions, while the remaining 25% account for the rest. These same results can be observed in the polar graph (Figure 4), where each bar represents the contributions of a student.

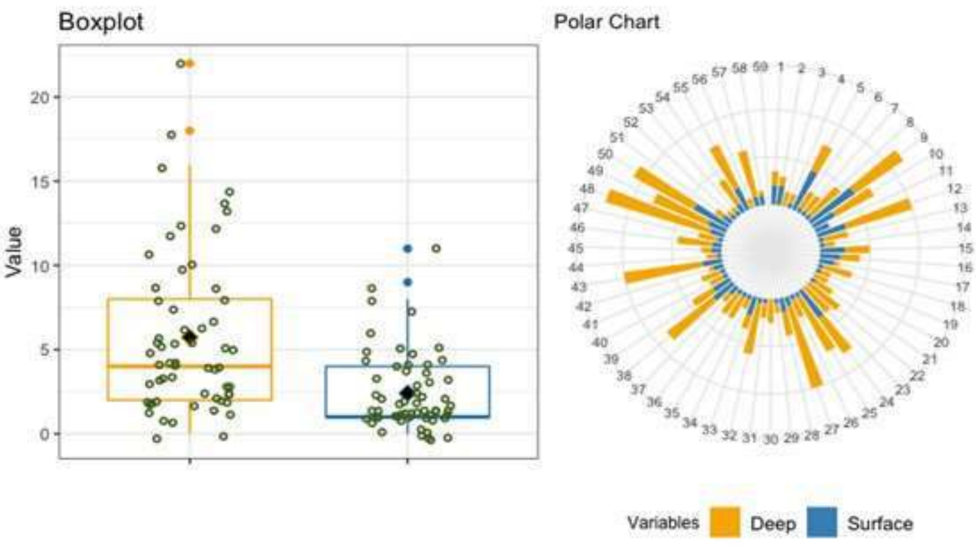
Figure 4
Community leadership based on participation in the online platform



Result 2: Level of learning reflected in the individual contributions

Figure 5 shows the results of the contribution quality analysis. It reveals that students produced a higher number of notes categorized as deep level (n=338; $\overline{x}$=5.73, Sd=4.78) compared to superficial level (n=142; $\overline{x}$=2.41, Sd=2.33). Furthermore, the results reveal types of participation (Figure 5). In other words, a few students predominantly created surface notes (e.g., S2), while others focused on producing deep notes (e.g., S27). However, there are also students who consistently contributed both surface and deep notes about educational research issues (e.g., see S9).

Figure 5
Deep Vs. Surface Notes



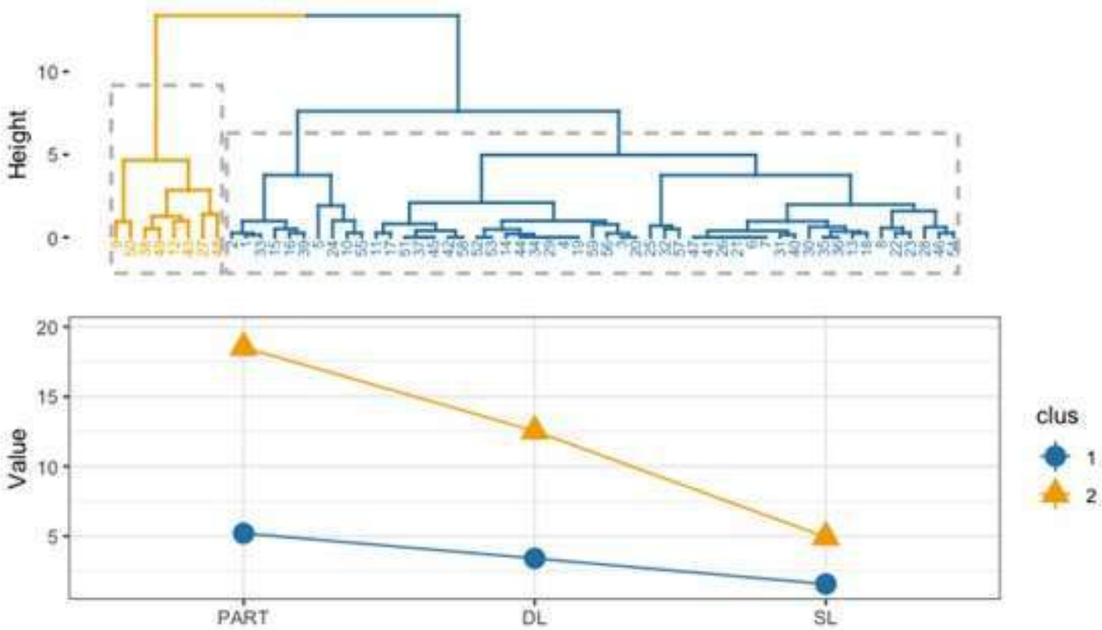
Result 3: Students´ patterns

To explore potential student profiles, a robust K-Medoids clustering algorithm was applied using the PAM method (Figure 6). To determine the optimal number of clusters, we employed two methods: the Gap Statistic and Silhouette. Both methods indicated an optimal number of 2 clusters. Cluster "C1" consists of 44 students ($\overline{x}_{Participation}$=5.2, $Sd_{Participation}$=2.38; $\overline{x}_{Deep}$=3.41, Sd_{Deep}=2.03; $\overline{x}_{Surface}$=1.57, $Sd_{Surface}$=1.3). Cluster "C2" comprises 15 students ($\overline{x}_{Participation}$=18.53, $Sd_{Participation}$=5.07; $\overline{x}_{Deep}$=12.52, Sd_{Deep}=3.96; $\overline{x}_{Surface}$=4.93, $Sd_{Surface}$=303).

Although both clusters include students who produce more deep notes than superficial ones, they show significant differences between each other in the three variables ($z_{Participation}$=-5.31, p-$value_{Participation}$<.001; z_{Deep}=5.02, p-$value_{Deep}$<.001; $z_{Surface}$=-4.58; p-$value_{Surface}$<.001). Moreover, they exhibit large effect sizes ($z_{Participation}$=.75; z_{Deep}=.74; $z_{Surface}$=.55). Interestingly, both clusters exhibit similar results in terms of the number of superficial notes. Additionally, cluster "C2", composed of leading students, even showed slightly more superficial notes than cluster "C1". Although the leadership cluster is mainly characterized by greater participation and a higher number of deep notes.

Figure 6

Cluster Dendrogram: 2 types of student's patterns

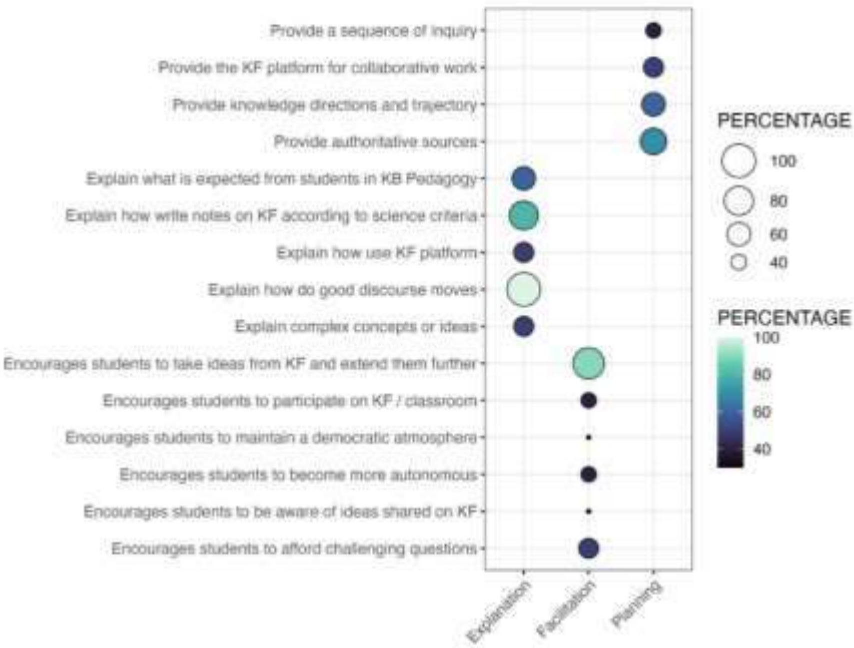


Result 4: Teaching scaffolds perceived by learners

Teaching scaffolds were organized into three types: planning, explanation, and facilitation (Figure 7). Qualitative evidence indicates that the students greatly appreciate collaborative planning scaffolds, where both they and the teacher actively participate in defining learning goals within the educational community. At the beginning of the course, the teacher plans with the students a map of the major questions they will investigate. The students affirm the importance of being part of the planning to feel ownership and responsibility for their own learning process. The students express that knowing what was expected of them and the purpose of their tasks helped them relate the activity to their learning and professional practice. On the other hand, the students state that the use of a flexible work sequence to guide the students' actions was a very effective scaffold. Additionally, the students highlight the access to different resources and materials provided by the teacher. Regarding explanatory scaffolds, especially at the beginning of the subject, it was crucial for the students to receive specific instructions on how to provide quality notes. Furthermore, the students emphasize the importance of the explanations for the proper use of the Knowledge Forum platform in accordance with the principles of Knowledge Building. This is because, initially, the students stated that for them, participating in the Knowledge Forum meant delivering a task on time, regardless of repeating the ideas that their peers had developed on the platform. However, with the explanations and examples from the teacher, they understood that participation in Knowledge Building means improving the ideas previously shared by their peers on the platform. Also, over time they began to appreciate the importance of basing their ideas on authoritative sources. Lastly, the students highlight creating advanced syntheses of previous notes as a very useful practice to encourage their participation. As for the facilitation scaffolds, the students express that the teacher posed (cognitively) challenging questions that generated greater commitment when delving into the collective ideas shared on the platform. Moreover, they appreciate that the teacher promoted diversity of ideas, continuously inviting them throughout the course to read the contributions of others, provide feedback, and ask questions to deepen their knowledge. Thus, the incremental efforts of the students, under the guidance of the teacher, were key in overcoming the initial difficulties. This means that the contributions and feedback from the teacher were important in overcoming the initial difficulties and guided the participation of the students throughout the course.

A percentage analysis was carried out to determine the most popular teaching scaffolds among students. According to the results obtained, students appreciated three types of teaching scaffolds during the implementation of KB pedagogy (Figure 7). A first type of scaffolding aims to provide a framework for collaborating on the improvement of ideas (e.g., KF, sequence of inquiry and other sources), and the shared goals of knowledge (creating a collaborative map of significant questions). Some of these scaffolds aim to help some students understand what is expected of them and how they can achieve it. Students need the teacher to explain what is expected of their participation in Knowledge Building pedagogy (i.e., questioning the content of other previous collective ideas, connecting various collective ideas, avoiding repetition of previous collective ideas, and improving upon previous collective ideas). They also value guidance on the quality standards they should meet (i.e., writing notes supported by evidence, clear and concise writing, citing, and referencing, etc.). Some of them also appreciate assistance in understanding how to use the Knowledge Forum platform correctly (i.e., appropriate use of the Knowledge Forum) and how to work in collaborative inquiry cycles to enhance their knowledge in research methods (i.e., working sequence). Likewise, students may already possess certain skills, but they require the teacher to provide them with a challenge and motivate them to confront it (i.e., encouraging to be more autonomous), or simply motivate them to do something (i.e., be aware of peers 'ideas reading notes on KF).

Figure 7
Teaching scaffolds to foster knowledge building



DISCUSSION AND CONCLUSIONS

In this study, the Knowledge Building model was implemented, an established educational model recognized for its significant impact in the field of Computer-Supported Collaborative Learning (CSCL). The purpose was to train students in the field of educational research. To evaluate the benefits of Knowledge Building, we have analyzed student participation on the Knowledge Forum platform.

Firstly, we analyzed the distribution of student participation in the Knowledge Forum by calculating the Gini coefficient (this coefficient provides objective information on how participation was distributed among members). The Gini coefficient results reveal a slight inequality in participation in the Knowledge Forum. This indicates that many students show a similar level of commitment, but some students were more active participants than their peers, and leadership roles were concentrated within a subset of students. While a perfect distribution of participation may not be feasible or ideal in practice, we can assert that there are certain thresholds of inequality that indicate some students delegate the responsibility to contribute to the community to their peers (Gutiérrez-Braojos et al., 2018). Therefore, in future studies, it would be advisable to use scaffolds that promote the rotation of leadership among students when teaching (see Ma et al., 2019).

Secondly, we analyzed the level of knowledge reflected in the students' contributions in the Knowledge Forum using the SOLO taxonomy. The results show that most contributions were of high quality. Some students provided greater consistency in contributing in-depth notes, while others offered a combination of in-depth or high-quality, and superficial or low-quality contributions. Furthermore, a deeper analysis was conducted to identify student profiles based on their contributions, leading to interesting findings. The results reveal that the cluster with more active or participatory students also shows a higher proportional constant regarding the relationship between in-depth and superficial notes. In other words, both clusters produce superficial notes, but highly participatory students not only have more notes in total but also tend to maintain a higher proportion of in-depth notes compared to superficial ones (see Cacciamani et al., 2021; Yang, Yuan et al., 2022). The variability in the quality of the notes prepared by students in the Knowledge Forum, regardless of cluster affiliation, could be explained by the complexity of the educational research topic (Gussen et al., 2023). This could indicate the need to implement evaluative technologies that help students monitor, recognize their difficulties, reflect, and seek timely support from peers, the teacher, or any other resource. Similarly, the teacher could use these evaluative technologies to identify students who require help understanding concepts that may be especially complex for them.

Thirdly, the results reveal that students valued a variety of teaching scaffolds consistent with previous findings (Zhu & Lin, 2023). Some of these scaffolds are related to establishing a set of objectives or meta-questions for the course from the start, as well as providing a heuristic or inquiry sequence to collaboratively address these issues. These results are aligned with the literature on learning regulation (Järvelä et al., 2023). For students to intentionally engage in the learning process and consequently regulate their behavior and thinking toward achievement, it is essential that they are aware of the objectives (and criteria) to be achieved in the course, as well as those steps that increase the chances of success (Van de Pol et al., 2019). Other teaching scaffolds that stood out are explaining and motivating students to take concrete actions in challenging moments to improve collective knowledge (e.g., see Bereiter & Scardamalia, 2016). This leads us to conclude that students may lack sufficient skills to collaborate effectively in knowledge construction, underscoring the relevance of educational models like Knowledge Building in today's education. Students also emphasized the importance of the teacher's explanations on specific topics (e.g., complex concepts). This supports research indicating that addressing the content of the educational research topic poses a cognitive challenge for students related to their knowledge background (e.g., Sweller et al., 2019) and the crucial motivational and intellectual support of teachers (Madison et al., 2022; Nind et al., 2020).

In summary, the implementation of Knowledge Building has positive effects on learning outcomes and the quality of discourse among participants, even though students may have different profiles. The results of this study, although improvable, demonstrate that students are capable of collectively constructing knowledge (Scardamalia & Bereiter, 2021). Previous studies have shown that in a classroom where Knowledge Buildind is implemented, all ideas are valued and contribute to progressive discourse (e.g., Tan et al., 2021). This inclusion benefits both high-achieving students and those with lower performance (e.g., Yang, Yuan et al., 2022). Collaborative work between these groups of students helps to advance knowledge through questions, explanations, additional materials, etc. For this, we have identified that teaching scaffolds play a crucial role in enhancing constructive participation in online discourse for all students in Knowledge Building environments (Zhu & Lin, 2023). This study contributes to our understanding of the specific ways in which teaching scaffolds support students in Knowledge Building. Likewise, this study provides strategies that can be used in other collaborative constructivist learning contexts.

Future research could investigate the effects that the use of Generative Artificial Intelligence (GAI), such as ChatGPT (García Peñalvo et al., 2024), could have on the quality of progressive student discourse (e.g., Tan et al., 2023), without negatively interfering with student learning. Some of the teaching scaffolds pointed out in this study could be covered with the use of ChatGPT. For example, reviewing and identifying improvements in the drafting of a note, synthesizing different ideas, or looking for analogies to an idea to facilitate its understanding. In addition, we suggest that future studies could focus on deepening the understanding and development of technologies associated with facilitating reflective assessments and encouraging participation. These technologies could take advantage of these findings about teaching scaffolds that are appreciated by students (Teo & Tan, 2023).

Finally, a limitation of this study is the sample size. Although the observed trends provide a useful preliminary view, the generalization of the results to a broader population is limited. A larger sample could offer a stronger and more diverse representation of the target population, allowing a more detailed analysis of variations within the sample. Therefore, understanding the effort involved in carrying out these applied research studies, we recommend that future studies coordinate efforts to expand the sample to overcome these limitations. Future research avenues also include conducting systematic reviews of Knowledge Building-based interventions.

NOTES

1. You can access resources on the implementation of KB and KF across various disciplines and educational levels: https://ikit.org/kbi/index.php/knowledge-building-resources/

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CRediT

Author 1: Actively participates in each role of CrediT (conceptualization, data curation, quantitative and qualitative formal analysis, funding acquisition, investigation, methodology, project administration, resources, software-programming-analysis, supervision, validation, visualization, writing original draft, writing-review editing, APA style, translation, review that this text is an original paper). Author 2: Actively participates in some roles of CrediT (data curation, qualitative formal analysis, collaborating with investigation, validation, collaborating with visualization, collaborating with writing-review editing, APA style, collaborate with the translation). Author 3: Actively participates in some roles of CrediT (collaboration with Data curation-validation-support as the third analyst, review that this text is an original paper). Author 4: Actively participates in some roles of CrediT (collaboration with Data curation-support as the third analyst and collaborate with APA style).

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Validation of the OCPBL model for online collaborative project-based learning

Validación del modelo ABPCL para el aprendizaje basado en proyectos colaborativos en línea

Marc Romero Carbonell - *Universitat Oberta de Catalunya, UOC (Spain)*
Teresa Romeu Fontanillas - *Universitat Oberta de Catalunya, UOC (Spain)*
Montse Guitert Catasús - *Universitat Oberta de Catalunya, UOC (Spain)*
Pablo Baztán Quemada - *Universitat Oberta de Catalunya, UOC (Spain)*

ABSTRACT

This contribution presents the validation of the Online Collaborative Project-based learning model based on the experience of a subject that is present in all the undergraduate programs in the Universitat Oberta de Catalunya called "ICT Competences". Based on mixed method research through an online survey that combines quantitative and qualitative data, the opinions of 978 students from the different university programs were gathered. The main aim of this research was to know students' opinions on the principal elements of the model and its transferability in academic and professional contexts. The contributions of the students are analyzed globally, by gender, and by undergraduate program. The presented results validate the model, but we suggest some adjustments in order to improve some aspects of the implementation process and open further research possibilities based on its application. As the main conclusions of the study, the results suggest the need to sequence students' asynchronous communication, adapting the different roles of the teams and to provide a more professional-oriented context for some of the activities in order to make the model more closely related to the professional field. As an aspect for improvement, students mentioned some difficulty in managing situations in which the established agreements were not complied with. Among the positive aspects are the relationship with peers, learning new digital tools and resources, acquiring soft skills such as empathy and teamwork, and learning to collaborate effectively online.

Keywords: online learning; collaborative learning; project-based learning; higher education.

RESUMEN

Se presenta la validación del modelo Aprendizaje Basado en Proyectos Colaborativos en Línea en el marco de una asignatura transversal de la Universitat Oberta de Catalunya denominada "Competencias TIC". La metodología seguida en esta investigación se enmarca en un diseño de métodos mixtos, combinando datos cualitativos y cuantitativos. Mediante un cuestionario con preguntas cerradas y abiertas se recabó la opinión de 978 estudiantes de los diferentes estudios de esta universidad, donde valoran los elementos fundamentales del modelo, así como su transferibilidad a los ámbitos académico y profesional. Las aportaciones se analizan en global, por género y por estudio. Se valida el modelo, y se sugieren algunas mejoras en aspectos de su implementación, abriendo nuevas posibilidades de investigación: se plantea secuenciar el trabajo asíncrono para permitir su implementación por todo el alumnado, adaptar los roles de los equipos de trabajo y contextualizar algunas actividades al ámbito profesional de cada estudio. Se concluye que el modelo es completamente transferible a otras asignaturas o estudios en línea. Como aspecto mejorable se menciona la dificultad de gestionar las situaciones en las que algún miembro del equipo no cumpla con los acuerdos establecidos, mientras que entre los aspectos positivos destacan la relación con los/las compañeros/as, el aprendizaje de nuevas herramientas y recursos digitales, la adquisición de habilidades relacionadas como la empatía y el aprendizaje de trabajar colaborativamente en línea.

Palabras clave: aprendizaje en línea; aprendizaje colaborativo; aprendizaje basado en proyectos; educación superior.

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INTRODUCTION

One of the main methodological innovations of the "Bologna process" in higher education has been placing the student in the centre, a consequence of the incorporation of competencies that connect students with a professional environment (Montero, 2010). This process remains open in response to changes in society, where the need arises to acquire new skills of use for professional development (Díaz-García et al., 2023).

Within the framework of the European Higher Education Area (EHEA), there is a need to incorporate active methodological approaches based on the implementation of the competences to be acquired. Among these active methodologies, collaborative learning has proven to promote competency learning effectively (Hernández et al., 2021; Okolie et al., 2022).

Collaborative learning combines the acquisition of the knowledge required by each discipline with the development of the competences necessary for the world of work, such as problem solving, social and communication skills, and individual collaborative competence, essential for any 21st century professional (Rios et al., 2020).

In the digital era, online work as part of collaborative work is common practice in many organizations, where team members must be able to communicate and collaborate effectively through digital platforms and online tools. This involves skills such as information and data management, organizing time and tasks efficiently, being able to work with people from different backgrounds and even at different times, and the need to remain up to date on the use of online collaborative tools, without neglecting the ethical and civic aspects (Guitert & Romeu, 2020).

To accompany students in this complex process, it is important that teachers know and take into account in their teaching design the differentiating characteristics and implications of online work, which we can find defined in Romero et al (2021), which points out the ten key components for online teaching-learning: active role of students, competencies, active and collaborative methodologies, varied typology of e-activities, synchronous and asynchronous communication, resources for teaching-learning, continuous assessment, role of teachers as guide, planning, stable learning environment, and well-defined tools.

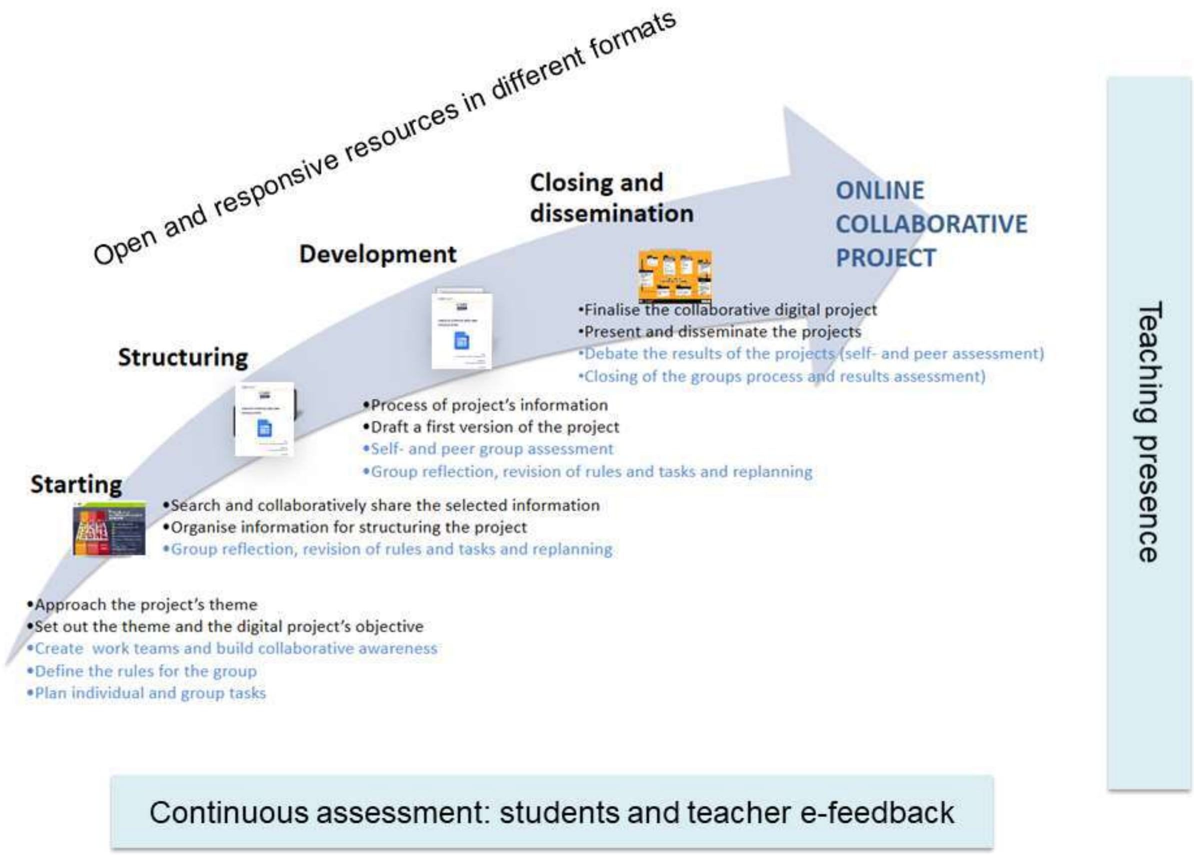
Collaborative learning is usually combined with active methodologies for group activities, one of the most common being Project Based Learning (PBL), characterized by encouraging autonomy, constructive research, achievement of objectives, collaboration, communication, and reflection based on projects anchored in the real world (Kokotsaki et al., 2016). Its growing implementation in various university degrees in different contexts is confirmed (Guo et al., 2020), and increasingly common in online contexts (Hernández-Arvizu et al., 2023).

The complex nature of the teaching-learning processes involved requires establishing systematic models so that their application allows activation of the mentioned aspects (asynchronous communication, continuous assessment, acquisition of competences, etc.) to allow a correct evaluation that involves feedback and improvement of the implemented processes.

Since its adaptation to the EHEA in 2009, the Universitat Oberta de Catalunya has included a transversal subject called "ICT Competencies", which served as the basis for the design of the Online Collaborative Project-Based Learning (OCPBL) model explained in Guitert et al. (2020), and whose implementation is the focus of this article.

The OCPBL sequences the process into four phases: Starting, Structuring, Development, and Closing and Dissemination, and three transversal axes: open resources, continuous and heterogeneous assessment, and teaching presence. Figure 1 shows the design of the model and its different elements:

Figure 1
ABPCL Model (Guitert et al., 2020)



The model can be adapted to different contexts, for example placing greater emphasis on some of the phases based on objectives in a subject. This article shows the validation of the model OCPBL based on the results obtained from a mixed methodological approach during the end of the first semester of the 2022-2023 academic year, where the students' perceptions of the ICT Competences subject offer a broader understanding of their vision of the application of the model for online learning teamwork. It also explores students' perception of the possibilities of transferring the model to the professional field. Therefore, to focus our research, we ask the following research questions:

- How do the students of the ICT Competences subject value the collaborative methodology in the OCPBL model?
- Are there significant differences between the elements of the model in terms of their transfer to the academic and professional spheres?

METHODOLOGY

This research uses mixed methods combining qualitative and quantitative data (Creswell, 2021) sequentially throughout the research process, both in the collection of information and in its analysis.

Data were gathered through an online questionnaire, appropriate for research in the social field (Babbie, 2017), and for collecting data from a population which is too broad to make a direct observation.

It was based on quantitative questions with answers on a Likert scale from 1 to 5 and a series of open questions based on the model, in which students can express their opinions on the different aspects of the subject.

The questionnaire was validated by the researchers of the Edul@b research group. Subsequently, the internal consistency of the closed questions was reviewed using Cronbach's alpha coefficient (Amirrudin et al., 2021), obtaining an index of 0.94. The redundancy found could be avoided by suppressing the ACAD variables (Table 1), obtaining an index of 0.89, but it was decided to keep them due to the relevance of the insight they provide on the transferability of the model.

The questionnaire asks demographic questions (age, gender, and study area) as well as questions related to the importance of aspects of network teamwork, specified in Table 1.

Table 1
Variables grouped by dimensions

Assess the importance of the following organizational aspects	ORG1	[The definition of group agreements]
	ORG2	[Review of agreements]
	ORG3	[Digital information management (shared files, etc.)]
	ORG4	[The initial planning]
	ORG5	[Planning review (replanning)]
Actions to communicate synchronously	SINC1	[Start an activity]
	SINC2	[Finish an activity]
	SINC3	[Streamline decision making]
	SINC4	[Resolve a conflict]
	SINC5	[Social interaction]
Relevance of the following tasks when evaluating your team's work	EVAL1	[Self-assessment]
	EVAL2	[Co-assessment]
	EVAL3	[Assessment of a project by colleagues]

Imagine that you find that one of the members of your group has not made any contributions. Assess the appropriateness of these actions to resolve the situation	CONF1	[Contact the person to find out what the problem is]
	CONF2	[Talk to the teachers and have them take the appropriate measures]
	CONF3	[Request an extension of the deadline while it is resolved]
	CONF4	[Continue the work with the rest of the team and say nothing]
	CONF5	[Exclude the person from the group and distribute their tasks]
Assess the degree of academic usefulness of the following elements	ACAD1	[Group operating agreements]
	ACAD2	[Group planning]
	ACAD3	[Role distribution]
	ACAD4	[Organization of digital information]
	ACAD5	[Presentation of digital information]
	ACAD6	[Using asynchronous communication]
	ACAD7	[Use of synchronous communication]
	ACAD8	[Assessment/Reflection of collaboration]
	ACAD9	[Conflict resolution strategies]
	ACAD10	[Consensus, argumentation, and negotiation]
	ACAD11	[Assessment of a project by colleagues]
Assess whether the following items are or can be transferable to your professional environment	PROF1	[Group operating agreements]
	PROF2	[Group planning]
	PROF3	[Role distribution]
	PROF4	[Organization of digital information]
	PROF5	[Presentation of digital information]
	PROF6	[Using asynchronous communication]
	PROF7	[Use of synchronous communication]
	PROF8	[Assessment/Reflection of collaboration]
	PROF9	[Conflict resolution strategies]
	PROF10	[Consensus, argumentation, and negotiation]
	PROF11	[Assessment of a project by colleagues]

The population comprises the entire student body of the ICT Competence subject in all UOC degree programs where OCPBL is applied, with a total of 3,731 students enrolled at the time of the study (end of the first semester of the 2022-2023 academic year). The administration of the questionnaire was confidential and anonymous, with a Google Form used to deliver it and to monitor the number of responses. The obtained sample is the result of the voluntary participation of students who responded, being representative of each of the courses where the ICTC subject is taught, including 26% of the population with a confidence level of 95% and a margin of error of 2.7%. Table 2 presents the population and sample data of the entire set, as well as the breakdown by study area.

Table 2

Composition of the population and the sample by study area

	E1 Law and Political Science	E2 Economy and Business	E3 Arts and Humanities	E4 Psychology and Educational Sciences	E5 Informatics and Communication
Population	918	1161	305	654	693
Sample	253	261	120	133	204
% population	28 %	22 %	39 %	20 %	29 %

The data analysis was conducted through a statistical analysis of the quantitative data with the free software program JASP and an analysis of the written discourse (Krippendorff, 2019) with live coding using the free software program QCAmap.

RESULTS AND DISCUSSION

Table 3 shows the results of the mean ratings (Mean), both overall and by gender, and standard deviation (SD) for each variable. The columns "Differences by gender" show the values of the *t* statistic and the p-value of the Student t test for independent samples. In the cases with significant Brown-Forsythe values, the Welch t test was also applied, obtaining the same conclusions. The columns "Differences by study area" show the F or H statistic for independent samples of more than two groups (an ANOVA or post hoc Dunn test was applied depending on the homogeneity of variances) and the corresponding p or p Holm value in each case.

Table 3

Assessment of teamwork variables: overall, by gender, and by study area

	Global		Women		Men		Differences by gender		Differences by study	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**t**	**p**	**F/H***	**p/pholm***
ORG1	4,17	1,00	4,24	0,97	4,05	1,05	2.910	0.004	1,403	0,231
ORG2	3,96	1,02	4,03	1,01	3,84	1,02	2.879	0.004	2,334	0,054
ORG3	4,38	0,82	4,45	0,80	4,26	0,84	3.498	< .001	0,506	0,731
ORG4	4,20	1,01	4,29	0,95	4,06	1,10	3.496	< .001	3,453	0,008
ORG5	4,24	0,93	4,30	0,93	4,13	0,93	2.730	0.006	3,259	0,011
SINC1	3,73	1,42	3,75	1,44	3,68	1,39	0.758	0.449	22,031*	<0,001*

	Global		Women		Men		Differences by gender		Differences by study	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**t**	**p**	**F/H***	**p/pholm***
SINC2	3,87	1,33	3,94	1,34	3,77	1,32	1.920	0.055	21,423*	<0,001*
SINC3	4,00	1,24	4,02	1,24	3,97	1,23	0.625	0.532	1,952	0,100
SINC4	3,72	1,42	3,76	1,43	3,63	1,41	1.413	0.158	11,205*	0,024*
SINC5	3,45	1,48	3,52	1,49	3,33	1,47	1.909	0.057	21,673*	<0,001*
EVAL1	4,11	0,99	4,21	0,96	3,95	1,02	3.856	< .001	2,427	0,046
EVAL2	4,18	0,94	4,25	0,93	4,04	0,96	3.367	< .001	1,913	0,106
EVAL3	4,18	0,97	4,23	0,96	4,01	1,01	2.257	0.024	0,833	0,505
CONF1	4,58	0,82	4,62	0,78	4,50	0,89	2.250	0.025	0,558	0,693
CONF2	3,34	1,33	3,37	1,36	3,30	1,29	0.839	0.402	2,133	0,075
CONF3	2,93	1,37	2,97	1,40	2,86	1,32	1.266	0.206	5,194	<0,001
CONF4	2,78	1,48	2,73	1,49	2,88	1,45	-1.574	0.116	1,592	0,174
CONF5	2,09	1,31	2,00	1,31	2,23	1,30	-2.672	0.008	22,200*	<0,001*
ACAD1	4,07	1,11	4,16	1,09	3,92	1,14	3.330	< .001	1,673	0,154
ACAD2	4,28	1,03	4,34	1,01	4,19	1,05	2.154	0.032	1,036	0,388
ACAD3	3,86	1,18	3,90	1,17	3,78	1,19	1.592	0.112	0,557	0,694
ACAD4	4,31	0,91	4,38	0,86	4,17	0,98	3.539	< .001	0,880	0,475
ACAD5	4,34	0,90	4,42	0,85	4,21	0,96	3.557	< .001	1,436	0,220
ACAD6	4,04	1,12	4,09	1,10	3,94	1,15	1.963	0.050	0,720	0,579
ACAD7	4,08	1,15	4,17	1,09	3,92	1,23	3.170	0.002	2,432	0,046
ACAD8	4,22	0,98	4,33	0,93	4,03	1,04	4.707	< .001	2,016	0,090
ACAD9	4,15	1,04	4,28	0,98	3,93	1,11	5.078	< .001	1,536	0,190
ACAD10	4,34	0,96	4,43	0,88	4,20	1,04	3.618	< .001	0,434	0,784
ACAD11	4,18	1,04	4,22	1,01	4,10	1,08	1.710	0.088	0,968	0,424
PROF1	4,12	1,11	4,19	1,07	4,01	1,16	2.455	0.014	2,262	0,061
PROF2	4,34	1,00	4,39	0,98	4,25	1,03	2.107	0.035	10,257*	0,036*
PROF3	3,97	1,18	4,02	1,16	3,87	1,20	1.900	0.058	0,975	0,420
PROF4	4,20	1,01	4,29	0,98	4,06	1,04	3.379	< .001	0,486	0,746
PROF5	4,20	1,02	4,30	0,99	4,04	1,05	3.914	< .001	0,837	0,501

	Global		Women		Men		Differences by gender		Differences by study	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**t**	**p**	**F/H***	**p/pholm***
PROF6	4,09	1,19	4,19	1,14	3,91	1,24	3.472	< .001	1,829	0,121
PROF7	4,34	1,01	4,40	0,97	4,22	1,07	2.769	0.006	0,949	0,435
PROF8	4,17	1,04	4,26	1,01	4,02	1,07	3.500	< .001	4,183	0,002
PROF9	4,34	0,96	4,44	0,91	4,17	1,02	4.198	< .001	12,367*	0,015*
PROF10	4,40	0,93	4,45	0,89	4,30	0,99	2.414	0.016	0,780	0,538
PROF11	3,89	1,23	3,97	1,22	3,77	1,25	2.427	0.015	3,534	0,007

Next, the overall results included in the previous table are discussed, along with additional findings from quantitative and qualitative elements to enable a more focused discussion by dimensions and study areas.

The results in Table 3 show that the general rating is very positive, with 28 of the 40 variables scoring an average value greater than 4, nine of them with an average rating between 3 and 4, and three with an average rating between 2 and 3. These results allow for the validation of the model and its overall application, while also helping to focus on areas for improvement.

It should be noted that in 28 of the 40 variables studied the differences between gender are significant and that in only two of the 40 variables the average rating of men is higher than that of women (CONF4 and CONF5).

The open question "After having worked as an online team in the subject, what do you take away as positive and what as negative?", was answered by 723 students, with the most notable positive aspects being the relationship with classmates, learning new tools and resources, acquiring soft skills such as empathy or responsibility, teamwork, and learning to work collaboratively online. A notable aspect needing improvement was the difficulty of managing some situations in which a member of the team did not comply with the established agreements.

The results regarding the first research question are now discussed:

How do the students of the subject "ICT Competences" value the collaborative methodology within the OCPBL framework?

The results reflected in Table 3 for each of the dimensions of the OCPBL model and its implementation in the ICT Competences (ICTC) subject are discussed, with a cross-sectional approach to the gender variable, and considering the four critical processes of networked collaboration: organization and planning, communication, evaluation, and making collaboration conscious (Guitert, 2022).

Organization

For each of the five ORG variables the following question is answered: "Rate the importance of the following organizational aspects". Two variables of transfer to the academic and professional field (ACAD3 and PROF3) are also included, with aspects closely related to the organization of teams, such as the distribution of roles.

Initial planning, as well as reviewing and adapting as the project progresses, are key elements for both PBL and online teaching which the model explicitly includes in the Starting, Structuring and Development stages (Figure 1). The students' high scores for the variables ORG4 (Mean = 4.20, SD = 1.01) and ORG5 (Mean = 4.24, SD = 0.93) reaffirm the usefulness of planning teamwork in online activities.

The definition and review of agreements (ORG1 and ORG2) are also elements that improve the effectiveness of teamwork, and aspects such as responsibility and respect for others' ideas (Pupik et al, 2023). The activities based on the OCPBL model insist on the importance of establishing prior agreements and reviewing them in each of the subsequent phases of the project in order to function more effectively and avoid critical situations or solve them if they occur. Students are satisfied with completing these tasks and find them useful for the development of teamwork: "Although it was challenging at first, creating the operational agreements helped us organize ourselves and prevented issues. We had to redo some aspects a couple of times, but they were very helpful." (CT68).

The ORG3 variable, digital information management (Mean = 4.38, SD = 0.82), is highly valued by students, and is also one of the aspects highlighted as positive in their qualitative assessment: "Learning in a virtual group environment, use of digital tools within the field of ICT and also in tasks such as creation of digital projects, planning, organization, innovation of ideas, etc." (CT57).

The assessment of this variable is explained by the sequenced and organized instructions provided in the ICTC subject to help manage the teams' information using Google tools, establishing the bases for the management of digital information throughout their studies.

The ORG variables are scored significantly higher by women than by men, although with small Cohen effect sizes (min = 0.15, max = 0.23).

On the other hand, the variables ACAD 3 and PROF3 with average ratings below 4 (3.86 and 3.97 respectively) lead us to rethink the management of roles in teamwork. The CTIC subject proposes establishing the roles of Coordinator, Secretary, and Manager. To improve this aspect, roles should be adapted to the most common and meaningful tasks of the students' degree course, following the indications of Sundlin et al. (2022), which provides guidelines on the importance of the context and a clear definition of roles for optimal implementation and in publications such as Belbin and Brown (2022), addressing the roles of professional teams in virtual environments.

Communication

To offer greater geographical and time flexibility to the members of the work teams, the OCPBL model proposes asynchronous communication, which allows studies to be compatible with other obligations. However, they are given the possibility of communicating synchronously at specific times, for example to reach consensus on urgent decisions, in line with other research indicating a good acceptance of synchrony as a supplementary mode of communication (Besser, 2023).

When asking about positive aspects and those needing improvement in the application of the model, we found comments in favour of asynchrony and its discovery: "I have learned a lot about the functioning of the tools used to do the project and the experience of having done work with asynchronous communication" (CT141). However, some difficulties in its application are also expressed: "working asynchronously represents an overload of work if the frequency and work of each person is not planned, since it involves being aware of the response of others" (CT248), although these are unrepresentative cases when compared to the overall responses to the questionnaire. In some cases, the use of synchrony is also valued positively at certain specific moments: "making a record of each meeting we held on Google Meet or a summary of what we talked about on WhatsApp, so that it would be reflected in the forum, taking into account that to carry out a project like this, with so many activities, you have to communicate a lot" (CS347).

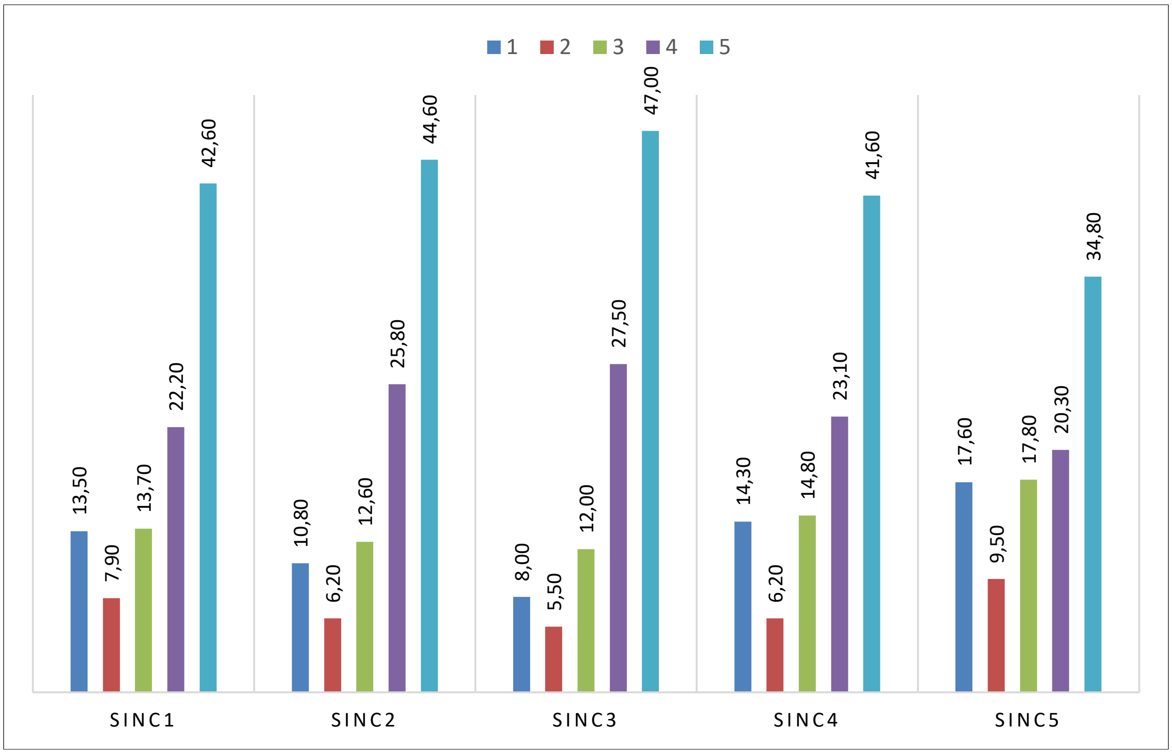
To find out in which situations students consider synchronous communication most useful, they were asked to evaluate five actions to be communicated synchronously (Table 3, SINC variables).

There are no significant differences regarding gender, although women tend to have a slightly higher average rating.

Regarding the global assessment, the highest-scoring action on average is the one corresponding to the SINC3 variable: Streamline decision making. Beyond the positive average rating of all of them, we see that in four of them the average rating is less than 4, and in one it is exactly 4, which places the group among the group of 12 out of 40 variables least valued. A more detailed analysis of the scores for each variable (Figure 2) shows the disparity of the ratings, as suggested by the high standard deviation of all of them.

Figure 2

Relative frequencies of the evaluations for each variable SINC in %



These results reinforce the priority use of asynchrony as a form of communication in the OCPBL model, while showing that the use of synchrony in some cases is valued positively by a significant percentage of the students (55.10% in the case of less valued variables such as SINC5), so it is reasonable to also maintain it as a reinforcement of asynchronous communication.

Assessment

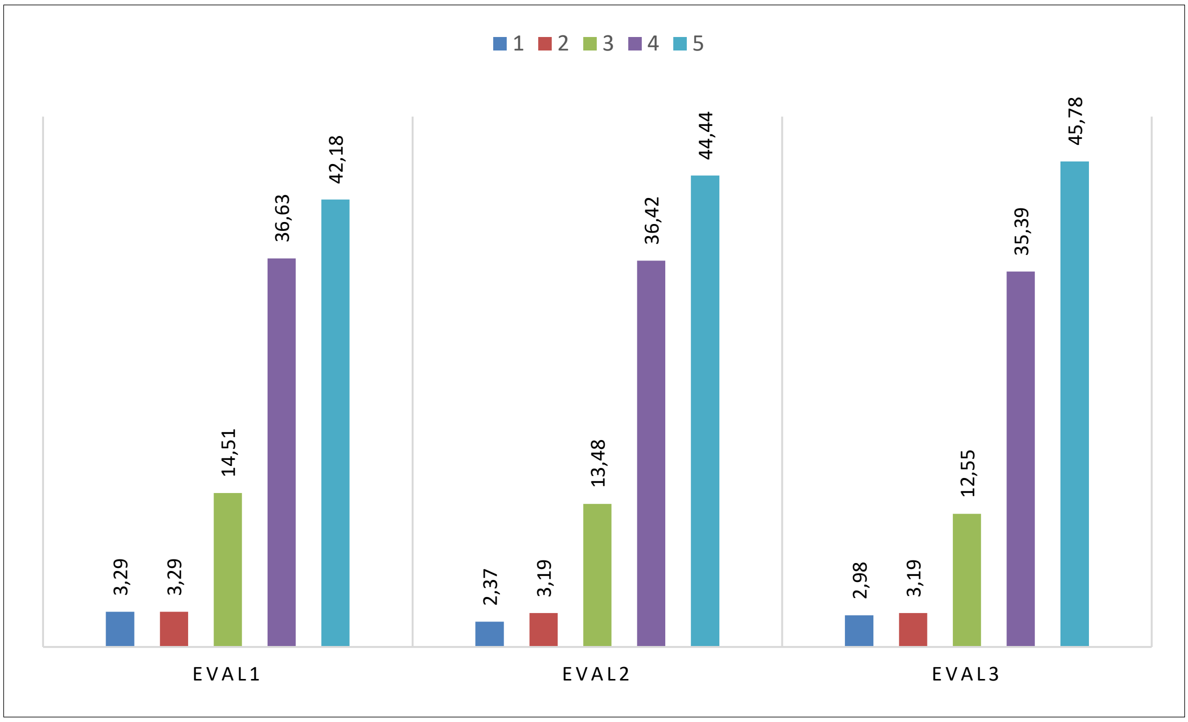
Another dimension of online collaboration is assessment, which in the OCPBL model proposal is continuous and based on a 360º vision, involving both teachers and students at different times and ways of evaluating (Romeu et al., 2016). To gather the students' perception of the assessment system, they were asked about the relevance of the three assessment methods in the CTIC subject (Table 3, EVAL variables).

The three variables obtain average ratings above 4, with the ratings of those tasks in which the work of others is evaluated (Mean = 4.18) being somewhat higher compared to self-assessment (Mean = 4.11).

The average ratings of the three assessment modes are very similar (4.11, 4.18 and 4.18). This is shown in more detail in Figure 3:

Figure 3

Relative frequencies of the evaluations for each variable EVAL in %



These results confirm “the positive perception of the student body regarding their active role in the assessment of their own learning process” (Cabrera et al., 2023) as progress is made towards the teaching objectives, given that these practices “promote participation and motivation with activities aimed at acquiring the competence of working as a team” (Planas-Lladó et al., 2020).

There are significant differences in the three variables according to gender, with effect sizes of 0.26, 0.22, and 0.15, always with a higher average rating for women. Although the results of the study do not provide a direct explanation for these differences, there is some agreement with studies such as González-Betancor et al. (2019), confirming that women engage in more detailed and reflective self-assessment processes than men.

Critical situations inherent to online collaboration

The implementation of the OCPBL model considers the possibility of conflicts appearing within some work teams, which may be more frequent in teams made up of members with prior knowledge and experience (Edmonson & Harvey, 2018) as is generally the case in the profile of UOC students.

As proposed in O'Neil and McLarnon (2018), dealing with conflicts in a controlled way can be beneficial for a team, since it promotes discussion, sharing different points of view, and the analysis of alternative paths of action. For this reason, an activity is proposed at the beginning so that students become aware of conflicts in teamwork and how to resolve them, participating in a virtual debate about a critical real case, including questions for reflection and action. Furthermore, they are also asked to explain the ways to resolve conflicts, for example, if members do not fulfil their assigned responsibilities. Even so, problems can always arise in the management of collaborative work throughout the process, due to multiple factors, such as a lack of agreement in the group formation process, the difficulties of evaluating individual participation in collective work or, to a greater extent, due to the "free rider" behaviour of some team members (Ramdeo et al., 2022).

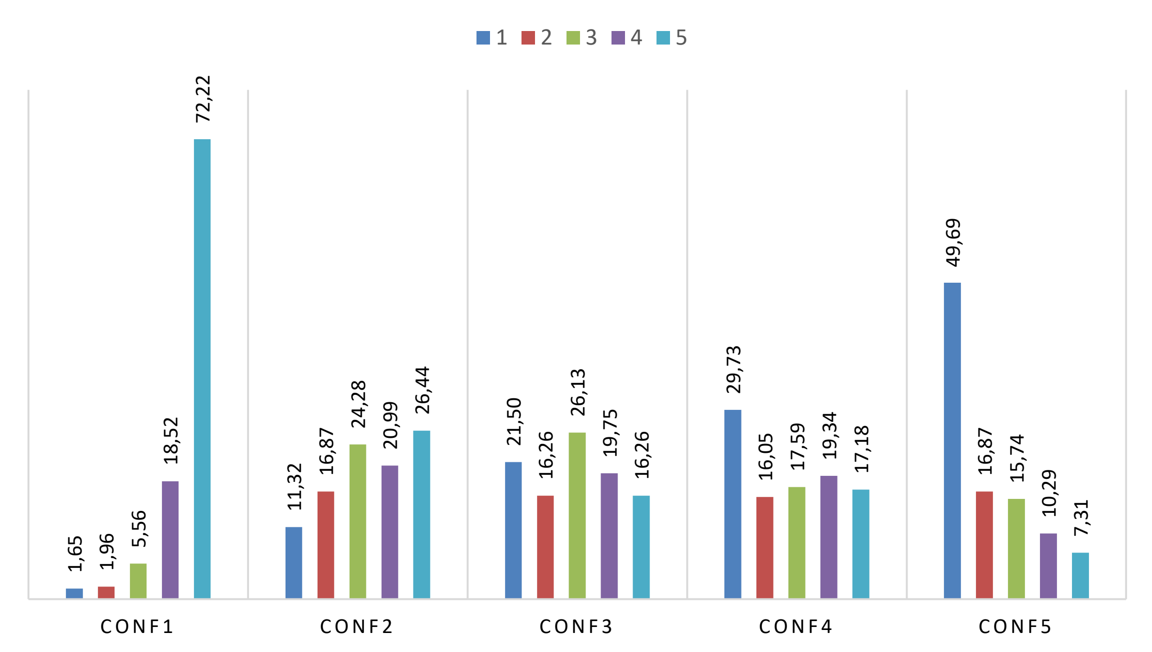
In the open response to the question "After having worked as an online team in the subject, what do you take away as positive and negative?", the most significant aspect mentioned for improvement is the difficulties in some cases in managing a lack of involvement by other team members: "it irritates me that my colleagues are not as involved as I am in the project" (CS34) is an illustrative example of this discomfort.

Regarding this same aspect, the following closed question was included: "Imagine that you find that one of the members of your group has not made any contribution. Rate the appropriateness of these actions from 1 to 5 to resolve the situation". The actions for which assessment was requested, as well as the results obtained for each of them, can be seen in variables CONF in Tables 1 and 3 respectively.

It should be noted that the two actions with the lowest rating, CONF4 (mean: 2.78; SD: 1.48) and CONF5 (mean: 2.09; Sd: 1.31), are the ones furthest from what is considered good conflict management (Pazos et al., 2022). The three best valued, and also closest to good conflict management, are enhanced by the characteristics of the OCPBL model, which has continuous assessment and teaching presence as its fundamental axes.

Figure 4 shows the relative frequency of the five levels of assessment for each of these variables:

Figure 4
Relative frequencies of the evaluations for each variable CONF in %



We can see how the sum of frequencies of the highest ratings are directly proportional to how appropriate each action is in relation to conflict management (90.74% in the variable CONF1 compared to 17. 59% in CONF5), while in the other three variables the percentage of each of the actions is more balanced, within the trend of each one.

This result reinforces the strategy followed of initially providing a series of resources and guidelines, explicitly addressing conflict management, and sending explicit messages in this regard throughout the course (Ou & Joyner, 2023).

The qualitative data show how teamwork and learning to work collaboratively online are the two most outstanding positive aspects: "It is positive to continue growing in the complex situation of working as a team, also in virtual environments" (CS39).

The results related to the second research question are discussed next.

Are there significant differences between the elements of the model in terms of their transfer in the academic and professional spheres?

The CTIC subject helps students in the different degree courses of the UOC to acquire the digital competences necessary for good performance, both academic and professional. So, in its design and implementation, it promotes the acquisition and transfer of these competencies to other environments, with particular relevance given to teamwork in online networks.

Next, the results of the ACAD and PROF variable groups are analysed (Table 3), which inquire about the academic and professional utility of the elements of the OCBPL model in their implementation in the CTIC subject.

Two variables associated with the management of digital information (ACAD5 and ACAD4) and two variables related to the management of collaborative work (ACAD10 and ACAD2) stand out with positive ratings. "Distribution of roles" stands out as the only one with an average rating of less than 4 (Mean = 3.86; SD = 1.18). Just as the first four reinforce the academic usefulness of online collaborative work and information management, the last variable leads us to rethink how the management of roles in teamwork is considered. The proposed distribution in the CTIC subject has generally established roles, as we already saw when discussing the results of the Organizational Aspects. The proposal for the roles of Coordinator, Secretary or Manager can be reviewed to see if an adaptation of the roles to the students' degree significantly increases the rating of this item.

In this case, the three highest-scoring variables are related to the management of group work and synchronous communication, while Distribution of roles is also valued below 4, but in this case the variable PROF11 is the one with the lowest average rating (Mean = 3.89; SD = 1.23).

The high ratings of all the variables in both dimensions allow us to affirm the possibilities of both academic and professional transfer of the model and its application. To go deeper into this analysis, Table 4 shows the level of significance of the differences in mean ratings of the same pair of variables for the academic and professional fields.

Table 4

Level of significance of the differences in mean ratings of the same pair of variables for the academic and professional field

	t	p		t	p
ACAD1/PROF1	-1627	0.104	ACAD7/PROF7	-7334	< .001
ACAD2/PROF2	-1819	0.069	ACAD8/PROF8	1522	0.128
ACAD3/PROF3	-3169	0.002	ACAD9/PROF9	-6324	< .001
ACAD4/PROF4	3437	< .001	ACAD10/PROF10	-1996	0.046
ACAD5/PROF5	4929	< .001	ACAD11/PROF11	8348	< .001
ACAD6/PROF6	-1452	0.147			

Significant differences are observed in the pairs of variables 3 (already discussed), 4, 5, 7, 9 and 11, barely significant in the pair of variables 10, and it is observed that there are no significant differences in the pairs 1, 2, 6 and 8.

The significantly higher rating of the ACAD11 variable (Mean = 4.07) "Assessment of a project by colleagues" compared to that of the PROF11 variable (Mean = 3.89) is justified, since the assessment of the projects is done for an academic purpose and planned specifically for the subject, so there is not much projection beyond this.

The ratings of pairs of variables 4 and 5, referring to the organization and presentation of digital information, are significantly higher in the academic dimension (Mean = 4.31 and Mean = 4.34) than in the professional dimension (Mean = 4.20 and Mean = 4.20), which can be explained by the fact that students put these skills into play in a very concrete way for the execution of the subject's activities. This makes us consider the possibility of contextualizing the activities more deeply by referring to real applications in a simulated work environment.

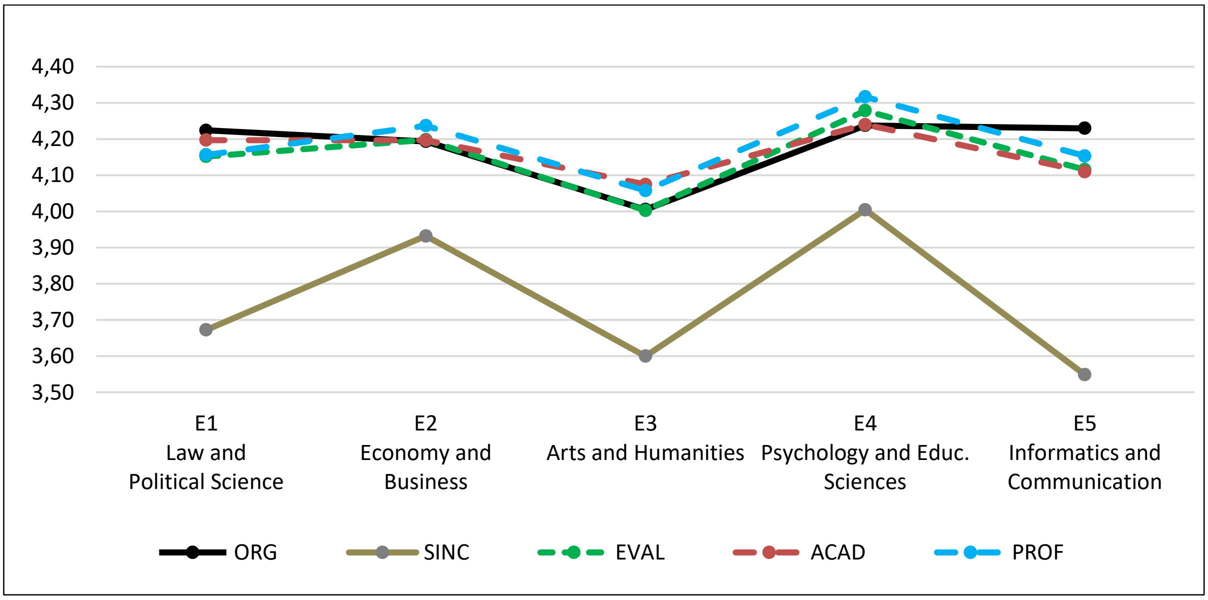
Synchronous communication (variable 7) has a higher rating in the professional field (Mean = 4.34) than the academic field (Mean = 4.08), probably because presence and/or constant online relationships are associated with work environments, in which asynchrony has less implementation.

Also, strategies for conflict resolution (variable 9) have a significantly higher value in the professional field (Mean = 4.34) than in the academic field (Mean = 4.15). This fact could be explained because conflicts are not very frequent in the subject, given the resources discussed when talking about the critical situations that students may find useful in future situations of their own professional environment.

To evaluate in more detail the transfer of the model and its implementation in the academic field, we now analyse the results obtained from comparing the average ratings of the variables across different study areas (Table 3).

Figure 5 shows the average ratings of each group of variables per study area.

Figure 5
Average ratings of each group of variables per study area



The variables EVAL, ACAD, and PROF show very similar average ratings across all study areas, with lower ratings in E3 and higher ratings in E4. In the SINC group, the averages are lower in each case compared to the other variables, with study areas E2 and E4 having higher ratings than the other three. In the ORG variable group, study area E3 has a lower average than the rest, which are very similar to each other.

This fact can be explained by the student profile, given that, on the one hand, Arts and Humanities students (E3) are more likely to be studying for personal fulfilment, which means these aspects have less value for their professional development, while E2 and E4 students usually study a degree which will be put to use in the professional field, and in turn, are more aware of the importance of the psychological processes inherent to teamwork.

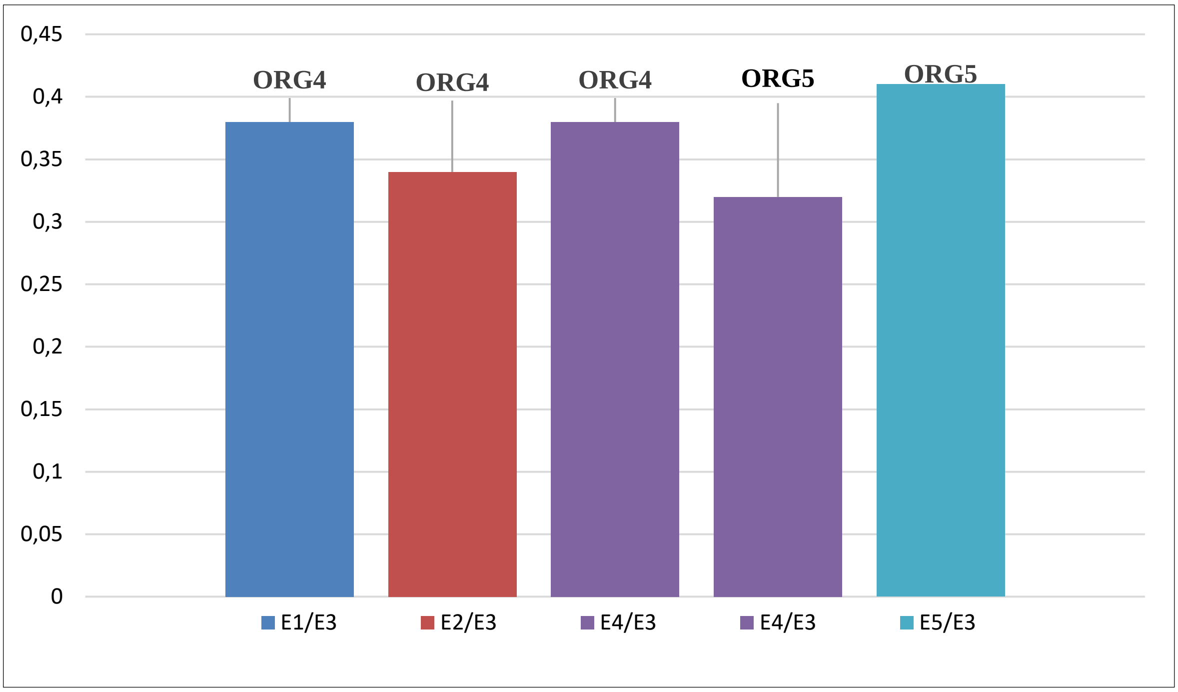
The group of variables SINC shows lower means compared to the rest of the variables in all study areas. This result is consistent with the emphasis placed on asynchrony from the CTIC subject, as discussed earlier in the Communication section.

Considering the level of significance of these differences (Table 3), no significant differences have been found in the assessment of the group of ACAD variables, while the SINC and PROF variable groups are the ones that present a greater number of variables with significant differences and effect sizes higher than the rest.

Analysing the group of ORG variables in more detail, two of them show significant differences among the study areas: ORG4 with p = 0.008 and ORG5 with p = 0.011.

Figure 6 shows between which study areas these differences occur, as well as the effect size in each case.

Figure 6
ORG variables with significant differences between study areas



We see that in these two variables, students from Arts and Humanities (E3) give average ratings below those of other study areas for the initial planning (ORG4) compared to E1, E2, and E4, and for the review of planning (ORG5) compared to E4 and E5.

The results allow us to confirm these differences, as well as those related to the rest of the variables, but they do not allow us to delve into the reasons for them, a matter that is beyond the scope of the present study. However, they provide sufficient evidence to generate instruments that help understand the reasons for the differences found.

CONCLUSIONS

Answering the first research question, the results show how positively students value the teamwork methodology of the OCBPL model, validating the model and its application as a whole, while also highlighting areas for improvement.

Aspects related to teamwork evaluation and organization are highly valued, suggesting improvement by assigning roles for teamwork tailored to the professional profiles of different study areas.

Given the difficulties that some students identified with asynchronous communication inherent in the model, a better sequencing of this type of communication is proposed as an improvement, providing more guidelines for its implementation and using synchronous communication at specific moments.

Including activities to raise awareness of what is involved in teamwork in a network is noted as important for reducing conflict, with learning how to work this way being one of the most highly valued aspects.

Regarding gender differences in evaluation, except for 2 out of 40 variables, the women's average rating is higher, with significant differences observed in 28 of them. Promoting gender equity in team formation, taking into account the reality of student demographics in each case, could harness the potential that these differences bring.

Regarding the second research question, the results support the complete transferability of the model to other subjects within the university or at other online universities, as well as to the professional sphere. While ratings are very positive, differences between some study areas have been found, inviting to further adaptation of activities to the professional reality of different fields of study.

As a limitation of the study, it should be noted that the model was designed and applied only in a specific subject, although this is mandatory and has a high impact in terms of the number of students, which plausibly restricts its transferability to other environments and subjects. Adapting and applying it to other university subjects and to other universities conducting fully-online training actions would help to further define and validate a globally transferable model.

This research has allowed us to know first-hand students' evaluation of the model, validating it globally. On the other hand, it also opens up future lines of research such as exploring the underlying reasons for gender and study-area differences.

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Assessing Teacher Digital Competence. An analysis integrating descriptive, inferential, and multivariate perspectives

Evaluación de la Competencia Digital Docente. Un análisis que integra las perspectivas descriptiva, inferencial & multivariada

Andrés Santiago Cisneros-Barahona – *Universidad Nacional de Chimborazo, UNACH (Ecuador)*
Luis Marqués-Molías - *Universitat Rovira i Virgili, URV (Spain)*
Gonzalo Samaniego-Erazo - *Universidad Nacional de Chimborazo, UNACH (Ecuador)*
Catalina Mejía-Granizo - *Banco Guayaquil (Ecuador)*

ABSTRACT

The holistic development of educators is of paramount importance for the successful integration of technological innovations into the curriculum, which will ultimately facilitate learners' progression through their educational journey. The construct of teaching digital competence (TDC) is instrumental within the realm of tertiary education, fostering both the pedagogical advancement of educators and the digital literacy of students. This research, which was undertaken at the Universidad Nacional de Chimborazo (UNACH) in Ecuador, employs the COMDID-A theoretical framework to examine the manifestation of digital competence (DC) among its faculty members. The study uses a descriptive-correlational method with a cross-sectional, non-experimental design and subjects selected probabilistically in the second half of the 2022 academic year. The integrity of the research was ensured through the application of rigorous reliability and validity assessments. The outcomes of the confirmatory factor analysis (CFA) revealed a commendable model fit, discerning four pivotal factors that explain 65 % of the variance and coincide with the dimensions delineated in the model. Only 39 % of the faculty sample surpassed the median level of TDC, with significant interdimensional correlations underscoring the pivotal role of the academic department and discipline. A correlation with doctoral qualifications suggests that advanced educational attainment fosters the enrichment of advanced TDC. The absence of significant correlations between educators' field of knowledge, employment status and time investment further illustrate the complexity of TDC development. A linear model analysis suggests a perceptual bias, rating adjunct faculty members as possessing superior competences compared to their tenured counterparts. These findings emphasize the crucial need for concerted competence development endeavors to increase the level of mastery in digital technologies (DT) within educational settings.

Keywords: digital literacy; digital technologies; teacher training; ICT; assessing digital competence; continuous teacher training.

RESUMEN

La formación integral de los educadores es fundamental para integrar la tecnología en el plan de estudios y guiar a los estudiantes en su proceso de aprendizaje. La Competencia Digital Docente (CDD) es clave en la educación universitaria, contribuyendo al crecimiento profesional y la alfabetización digital de los estudiantes. Este estudio en la Universidad Nacional de Chimborazo (Unach), Ecuador, usa el marco conceptual COMDID A para analizar la Competencia Digital (CD) en sus profesores. La metodología es descriptivo-correlacional con diseño transversal no experimental. La muestra, fue seleccionada probabilísticamente en el segundo período académico de 2022, y se sometió a pruebas de confiabilidad y validez. Los resultados del Análisis Factorial Confirmatorio (AFC) indican una adecuada adaptación, identificando cuatro factores que explican el 65 % de la variabilidad y se relacionan con las cuatro dimensiones del modelo adoptado. Solo el 39 % de los profesores supera el nivel medio de CDD. Se encontraron relaciones significativas entre las dimensiones del instrumento, destacando la importancia de la facultad y la carrera del profesor. La correlación con el grado doctoral sugiere que niveles más altos de formación influyen en el desarrollo de CDD avanzadas. No se observaron correlaciones con el área del conocimiento de la formación y el tiempo de dedicación del profesorado. El modelo lineal evidencia que los profesores ocasionales son percibidos como más competentes que los titulares. Estos resultados resaltan la necesidad de enfocarse en el desarrollo de competencias para mejorar el dominio de las Tecnologías Digitales (TD) en el aula.

Palabras clave: alfabetización digital; tecnologías digitales; formación del profesorado; TIC; evaluación de competencias digitales; formación continua docente.

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INTRODUCTION

In the early 21st century, educators are faced with the crucial need to acquire skills that enable the seamless integration of digital technologies (DT) into the pedagogical process (Bond et al., 2018; Cabero-Almenara et al., 2021). This necessity is underscored by a paradigm shift in which higher education institutions are urged to transcend mere digitization and to instead aspire to genuine digital renewal. Such an endeavor aims to leverage the full spectrum of digital resource capabilities, thereby optimizing the educational potential of the academic landscape (García-Peñalvo et al., 2020).

The advent of the Internet and DT has ushered in an age of unlimited access to information and opportunities. Yet, disparities in individual capacities to harness these opportunities has given rise to a digital divide that has impeded inclusive development. This skills gap poses significant challenges, particularly for those lacking basic digital competence (DC), which affects their access to employment, education services, and civic engagement (Juárez Arall & Marqués Molías, 2019).

This contemporary challenge brings with it the need to encourage educators to deliberate, analyze, and comprehend the omnipresence of DT within the instructional milieu (Gallardo Echenique et al., 2011). It is therefore a challenge that can only be taken on by recognizing the importance of engaging in continual professional development processes aimed at enhancing teaching, research, and administrative competences in the use of digital tools (Cuadrado et al., 2020; Esteve-Mon et al., 2016; Silva Quiroz & Miranda Arredondo, 2020). The application of cooperative learning strategies in higher education, especially within the context of the training of future educators, has emerged as a critical endeavor. The integration of digital teaching skills is thus a pressing necessity, and the incorporation of digital tools (DTs) must be advocated for within higher education classrooms (Huertas Abril, 2018).

The symbiotic relationship between DC and teacher digital competence (TDC) is intricate and interconnected. DC encapsulates the range of skills and understanding required for the effective use of DT across diverse contexts, encompassing both personal and professional domains. Conversely, TDC accentuates the specific spectrum of DC that educators must cultivate to effectively integrate DT into their instructional practices and the teaching-learning process. DC lays the foundational bedrock for TDC, empowering educators to navigate technologies more adeptly in their classrooms. TDC thus includes the ability to use DTs, critically evaluate online resources, foster digital literacy among students, and adapt pedagogical strategies for the successful incorporation of technologies within the educational setting.

The centrality of TDC in embedding DT into teaching and learning processes cannot be overstated. The construct not only catalyzes the professional development of educators but also nurtures students' digital literacy, thus fostering a digitally competent future workforce (Domingo-Coscollola et al., 2020). Institutions of higher education are advised to initiate and support instructional programs designed to furnish educators with the DC they require. These types of initiatives are fundamental in the process of equipping students with capabilities essential to success in both the academic and professional arenas (Gutiérrez-Castillo et al., 2017; Juárez Arall & Marqués Molías, 2019; Sánchez-Caballé et al., 2020). The formal acknowledgment and validation of these competences via certification processes are deemed crucial milestones in the continuum of teacher professional development (Verdú-Pina et al., 2023). Such certifications reflect educators' adeptness in the integration of DT into their pedagogical practices, concurrently fostering a rise in educational quality benchmarks. Thus, systematically monitoring and critically assessing the relevance and applicability of these certifications is of paramount importance to ensure they are aligned with the evolving requirements of the digital educational landscape.

Within this dynamic and perpetually evolving educational landscape, myriad factors surface that are fundamentally linked to both DC and the overarching higher education ecosystem. This interconnection extends to scholarly research and the theoretical delineation of DC and TDC (Cisneros-Barahona et al., 2024). Furthermore, this complexity encompasses the methods employed in assessing the proficiency levels and developmental trajectories of these competences.

Study and conceptual basis

The academic discourse surrounding the conceptualization of digital skills is characterized by a rich tapestry of terminology (Biel & Ramos, 2019; Cateriano-Chávez et al., 2021; Gallardo Echenique, 2013). The interrelation between *media literacy* and *digital media literacy* is profound and encompasses the ability to navigate information across disparate modalities (Buckingham, 2007; Wilson et al., 2011).

Concurrently, *multimodal literacy* emphasizes the synergetic integration of various communicative modalities and cognitive processes, facilitating the discernment and interpretation of information presented in visual formats. This is juxtaposed with *multiple literacies*, which embodies a *multimodal* capacity including the creation of content using written, visual, auditory, gestural, or spatial approaches (Kress et al., 2014; Mills & Unsworth, 2017).

Computer literacy is defined as mastery of computer applications and the management of information (Buckingham, 2015; Poynton, 2005) and lays the groundwork for more nuanced competences such as *informational literacy*, *ICT literacy, e-competences, and e-literacy*. These competences are deeply entrenched in a critical perspective on DT, which advocates for ethical information management across diverse contexts (Oxbrow, 1998; Rockman, 2005; Schneckenberg & Wildt, 2006; Somerville et al., 2007).

The scholarly contribution of Spanish authors to the burgeoning corpus of literature on DC is noteworthy Cisneros-Barahona, Marqués Molías, Samaniego-Erazo, Uvidia-Fassler, De la Cruz-Fernández & Castro-Ortiz, 2023; Cisneros-Barahona, Marqués-Molías, Samaniego-Erazo, Uvidia-Fassler, Castro-Ortiz & Villa-Yánez, 2023). At the international level, *digital literacy* is the preferred nomenclature, while within the European discourse, it is synonymously employed with the concept of DC (Almås & Krumsvik, 2008). Digital literacy encapsulates the technical and procedural competence needed for the effective engagement with digital environments and includes the cognitive, motor, sociological, and emotional dimensions (Aviram & Eshet-Alkalai, 2006; Eshet-Alkalai, 2009; Jones-Kavalier & Flannigan, 2006; Martin & Grudziecki, 2006; Rangel Baca & Peñalosa Castro, 2013).

Digital competence is described as a holistic amalgamation of values, beliefs, knowledge, skills, and attitudes across technological, informational, multimedia, and communicative domains. It manifests as a multifaceted competence that educators cultivate to integrate DT into their pedagogical praxis (Gisbert Cervera & Esteve Mon, 2011). Its essence lies in the effective management of information for the construction of knowledge (Gutiérrez, 2011), encompassing safe, critical, and responsible use of DT for educational, social, and interactive purposes. This competence includes *information and data literacy*, communication and collaboration, *media literacy*, digital content creation, online safety, intellectual property, problem solving, and critical thinking (Council of the European Union, 2018).

The construct of TDC is presented as a composite competence comprising an array of capabilities, skills, and attitudes acquired through professional development (Lázaro-Cantabrana et al., 2019). It is further described as a set of competences required for 21st-century educators to expand their educational praxis and facilitate their own continuous professional growth (INTEF, 2017).

DC baseline perspectives

In the contemporary educational context, the emergence of an array of TDC reference frameworks, developed by diverse institutions, organizations, and academics in the European arena, reflects the substantive evolution of the domain of DC (Cisneros-Barahona, Marqués Molías, Samaniego Erazo, Uvidia-Fassler & de la Cruz-Fernández, 2023; Cisneros-Barahona, Marqués-Molías, Samaniego-Erazo, Uvidia-Fassler, De la Cruz-Fernández & Castro-Ortiz, 2022). These frameworks have been instrumental in delineating conceptual models, essential dimensions, reference standards, key indicators, and pivotal components, thereby facilitating nuanced comprehension and fostering the propagation of TDC. The diversity inherent in these approaches is illustrated in Table 1, which summarizes some of the most significant contributions to this area of inquiry (Cabero-Almenara et al., 2020; Cisneros-Barahona, Marqués-Molías, Samaniego-Erazo, Uvidia-Fassler, Castro-Ortiz & Rosas-Chávez, 2022; Lázaro-Cantabrana et al., 2019; Palau et al., 2019; Pérez-Escoda et al., 2019). Each approach offers a distinctive and enriching perspective on the conceptualization and operationalization of TDC, allowing for the exploration of the multidimensional nature of these competences within education today.

Table 1
TDC frameworks and models developed over time

Year	Name	Reference
2000	National Educational Technology Standards for Teachers (NETS·T)	(ISTE, 2000)
2002	Raising the standards: A proposal for the development of an ICT competency framework for teachers	(CDEST, 2002)
2006	Technological pedagogical content knowledge: A framework for teacher knowledge	(Mishra & Koehler, 2006)
2006	A repository of techno-pedagogical skills for teaching staff	(Bérubé & Poellhuber, 2005)
2008	NETS for Teachers: National Educational Technology Standards for teachers	(ISTE, 2008)
2008	ICT competency framework for teachers	(Unesco, 2018)
2008	Professional standards for qualified teacher status and requirements for initial teacher training	(TDA, 2008)
2009	A teacher education model for the 21st century	(National Institute of Education, 2009)
2009	A proposal of framework for professional development of Turkish teachers with respect to information and communication technologies	(Kabakçi, 2009)

Year	Name	Reference
2009	The digital competence of higher education teaching staff for the knowledge society: A model for the integration of digital competence in teacher professional development	(Pozos Pérez, 2009)
2011	UNESCO ICT competency framework for teachers	(Unesco, 2011)
2011	Higher education computer science and internet certificate	(MESR, 2011)
2011	ICT competences and standards for the teaching profession	(Ministerio de Educación de Chile, 2011)
2013	Common framework for teaching digital competence: Draft with proposed descriptors v 1.0	(INTEF, 2013)
2013	DigiLit Leicester supporting teachers, promoting digital literacy, transforming learning initial project report DigiLit Leicester	(Fraser et al., 2013)
2013	ICT competences for teacher professional development	(Ministerio de Educación Nacional de Colombia, 2013)
2014	Teacher educators' digital competence	(Krumsvik, 2014)
2014	Web-based self- and peer-assessment of teachers' digital competences	(Põldoja et al., 2014)
2015	Development of a rubric to assess the teacher's digital competence	(Lázaro-Cantabrana & Gisbert-Cervera, 2015)
2016	ICT competences model for teachers: A proposal for the construction of innovative educational contexts and the consolidation of learning in higher education	(Hernández Suárez et al., 2016)
2016	Resolution ENS/1356/2016, by which the definition of digital teaching competence is published	(Departament d'Ensenyament. Generalitat Catalunya, 2016)
2017	Digital competence of educators DigCompEdu	(Redecker & Punie, 2017)
2017	Example title: Professional digital competence framework for teachers	(Kelentri et al., 2017)
2017	Common Framework for Teacher Digital Competence	(INTEF, 2017)
2017	Standards for educators	(ISTE, 2017)
2018	A rubric to assess the digital competence of higher education professors in the Latin American context	(Lázaro-Cantabrana et al., 2018)
2018	ICT Competency framework for teachers	(Unesco, 2018)
2018	Teaching digital competence of teachers in Catalonia	(Departament d'Ensenyament. Generalitat Catalunya, 2018)
2020	European Framework for the Digital Competence of Educators	(INTEF, 2020)
2022	Framework for teaching digital competence	(INTEF, 2022)

Moreover, the acknowledgment of accreditations for the purpose of validating TDC has emerged as a pivotal factor within this discourse. In the Spanish context, some of the more notable certifications include *ACTIC, CODIX, TuCertiCyL*, and the *DC Accreditation* in Asturias. However, the prominence of international certifications such as the *IC3 Digital Literacy Certification* offered by Pearson and the *I-SKILLS* program developed by the *Educational Testing Service* (ETS) points to a distinct evaluative approach towards essential digital skills. Beyond these, the *International Computer Driving License* (ICDL) represents a flagship accreditation spanning a wide range of DC. The French context further introduces the *Computer and Internet Certificate C2i*, specifically targeting the accreditation of DC among students, thereby accentuating the global landscape of TDC validation efforts (Verdú-Pina et al., 2022).

Frame of reference: COMDID-A

The use of the COMDID-A questionnaire within the framework of this research is predicated on the need for an evaluative tool that has not only been customized for the nuanced appraisal of TDC, but that also reflects the specific requirements and the distinct contexts of the educational practitioners. The meticulous design and calibration of this instrument played an instrumental role in collecting data of profound relevance and significance with which to precisely address the objectives of the study.

The instrument's intrinsic strengths, derived from its prior validation and its tailored adjustment to the Latin American educational landscape, confer upon the COMDID-A questionnaire a high degree of efficacy and applicability (Cisneros-Barahona, Marqués-Molías, Samaniego-Erazo, Mejía-Granizo & De la Cruz-Fernández, 2023; Lázaro-Cantabrana et al., 2018; Lázaro-Cantabrana & Gisbert-Cervera, 2015; Usart Rodríguez et al., 2020). This regional adaptation provides the instrument added value, ensuring its cultural relevance and alignment with the unique attributes of the educational context in Latin America.

Furthermore, the process of developing a rubric for the assessment of TDC was informed by an extensive review of the literature and existing theoretical constructs, as shown in Table 2. This endeavor has culminated in the formulation of a proposed rubric that encompasses foundational elements such as dimensions, scopes, and key concepts required for the establishment of indicators and the definition of development levels. These elements are described in Lázaro-Cantabrana et al. (2018) and Lázaro-Cantabrana and Gisbert-Cervera (2015), which provide a detailed, structured overview of the rubric's critical components. It facilitates a deeper understanding of the rubric's construction, ensuring its uniform interpretation and application by evaluators, thereby enhancing the integrity and consistency of the TDC assessment process.

The principal aim of this research is to quantify the extent of DC among the faculty members at UNACH, Ecuador, employing the COMDID-A theoretical framework (Lázaro-Cantabrana et al., 2018). The research seeks not only to gauge the degree of DC among the teaching staff, but also to determine its interrelations with a multiplicity of variables pertinent to academic personnel, including the domain of knowledge associated with both undergraduate and postgraduate qualifications, departmental affiliation, academic program, employment status, and the acquisition of doctoral credentials. The methodological approach adopted for this purpose is descriptive-correlational, encapsulated within a non-experimental, cross-sectional study design. The sample was selected through probabilistic means during the second academic term of 2022. To ensure the robustness and integrity of the construct under study, a series of factors were observed to guarantee methodological rigor, including the application of Cronbach's alpha tests for reliability assessment and a confirmatory factor analysis (CFA) for validity verification. Spearman's Rho was used as a statistical tool to explain correlations among the variables, and a bifactorial general linear model (ANOVA) was applied to explain the impacts of specific variables, namely employment relationship and academic program, on levels of TDC, thereby contributing to a nuanced understanding of the factors influencing digital proficiency within the academic sphere.

Table 2

Theoretical references used for the definition of the elements of the COMDID rubric (adapted from Lázaro-Cantabrana & Gisbert-Cervera, 2015*)*

Theoretical Referent	Rubric Element	Result
(Ferrari et al., 2013; Generalitat de Catalunya, 2015; ISTE, 2008; Unesco, 2008, 2015)	TDC Areas	1. **Classroom:** Educators engage in the use of digital tools within the learning environment, orchestrating and scheduling teaching-learning (T-L) endeavors facilitated by digital innovations. This encompasses holistically managing the educational space, monitoring, and assessing learner progress via digital means, and strategically planning T-L initiatives aimed at improving students' DC. 2. **Center**: Faculty members are tasked with the use and maintenance of the educational institution's digital frameworks and technological assets. This role extends to upholding the digital ethos of the institution, executing pedagogical oversight, and coordinating the institution's digital resources. Furthermore, educators are expected to assimilate and personalize the institution's technological training methods, thereby fostering an integrated digital culture within the educational context. 3. **Educational community and environment:** Within the broader educational community and its environs, teachers are instrumental in mobilizing and systematizing the institution's resources towards fostering societal engagement. This facet underscores the pivotal role of educators in leveraging educational assets for broader community participation and digital inclusivity. 4. **Professional development:** Educators are expected to cultivate and refine their personal learning environments (PLEs), foster expansive professional networks, and maintain a digital presence. This includes an enduring commitment to professional growth and the exemplification and leadership in the adoption of digital technologies. Such endeavors not only improve their pedagogical practice but also serve as a model for the integration of digital technologies within the educational landscape.
(Ferrari et al., 2013; Fraser et al., 2013; ISTE, 2008; Larraz Rada, 2013; Ministerio de Educación de Chile, 2011; Unesco, 2008, 2015)	TDC Dimensions	1. Teaching, curriculum, and methods. 2. Planning, organization and management of digital spaces and technological resources 3. Relational, ethical and security issues 4. Personal and professional factors

(Ferrari et al., 2013; Generalitat de Catalunya, 2015; ISTE, 2008; Larraz Rada, 2013; Ministerio de Educación de Chile, 2011; Unesco, 2008, 2015)	Key Concepts for TDC Indicators Definition	1.1 Teacher planning and digital competence 1.2 Digital technologies as facilitators of learning 1.3 Data processing and knowledge creation 1.4 Attention to diversity 1.5 Student assessment, tutoring and monitoring 1.6 Methodological approach of the academic unit 2.1. Learning environments 2.2. Managing digital technologies and programming 2.3. Spaces with digital technologies at the educational center 2.4. Projects for the incorporation of digital technologies 2.5. Instructions for digital technologies 3.1. Ethics and safety 3.2. Digital inclusion 3.3. Communication, dissemination, and transfer of knowledge 3.4. Digital content and the educational community 3.5. Digital identity of the center 4.1. Free access to information, creation, and dissemination of teaching materials with open licenses 4.2. Leadership in the use of digital technologies 4.3. Lifelong learning 4.4. Virtual learning communities: formal, informal, and informal lifelong learning 4.5. Personal learning environment (PLE) 4.6. Identity and digital presence
(Churches, 2007; ISTE, 2008; Larraz Rada, 2013)	TDC Levels of development	1. Beginner 2. Intermediate 3. Expert 4. Transformer

METHODS

Design

This research is based on a methodological framework that makes use of a descriptive-correlational approach underpinned by a non-experimental, cross-sectional study design (Bisquerra, 1989; Ramos-Galarza, 2020).

Population and sample

The study's population consists of the professors at UNACH, totaling 690 faculty members during the academic term under study. A probabilistic sampling strategy was employed to ensure a representative cross-section of the population. The sample size exceeded the minimum threshold (452) (Badii et al., 2008), with 511 educators participating, surpassing the requisite ratio of 5 samples per item for confirmatory structural analysis. The study made use of the COMDID-A rubric, an instrument made up of 22 distinct items (Hair JR et al., 2022).

The resulting sample represents 50 % of the targeted academic population, a figure supported by a statistical confidence level of 97 %. Participation rates and distribution are shown in Table 3.

Table 3

Characterization by study variables: Sample

Graduate degree knowledge Area	Employment Relationship		Total
	Full	Adjunct	
Education	74	50	124
Art & Humanities	1	12	13
Social Sciences, Journalism, Information and Law	6	22	28
Administration	34	46	80
Natural Sciences, Mathematics and Statistics	10	17	27
Information and Communication Technologies	12	17	29
Engineering, Industry & Construction	17	39	56
Agriculture, Forestry, Fisheries and Veterinary	1	2	3
Health & Wellness	40	97	137
Services	10	4	14
Total	**205**	**306**	**511**

Data collection instrument

The data was collected for this study by means of the administration of the COMDID-A questionnaire, an instrument carefully designed to assess the DC of in-service educators. It is a specialized analytical tool offering a nuanced and comprehensive exploration of the critical dimensions inherent to DC within the pedagogical domain. Figure 1 shows the structured composition of the COMDID-A questionnaire, illustrating the interconnected dimensions and indicators that underpin this evaluative framework (Lázaro-Cantabrana et al., 2018; Lázaro-Cantabrana & Gisbert-Cervera, 2015).

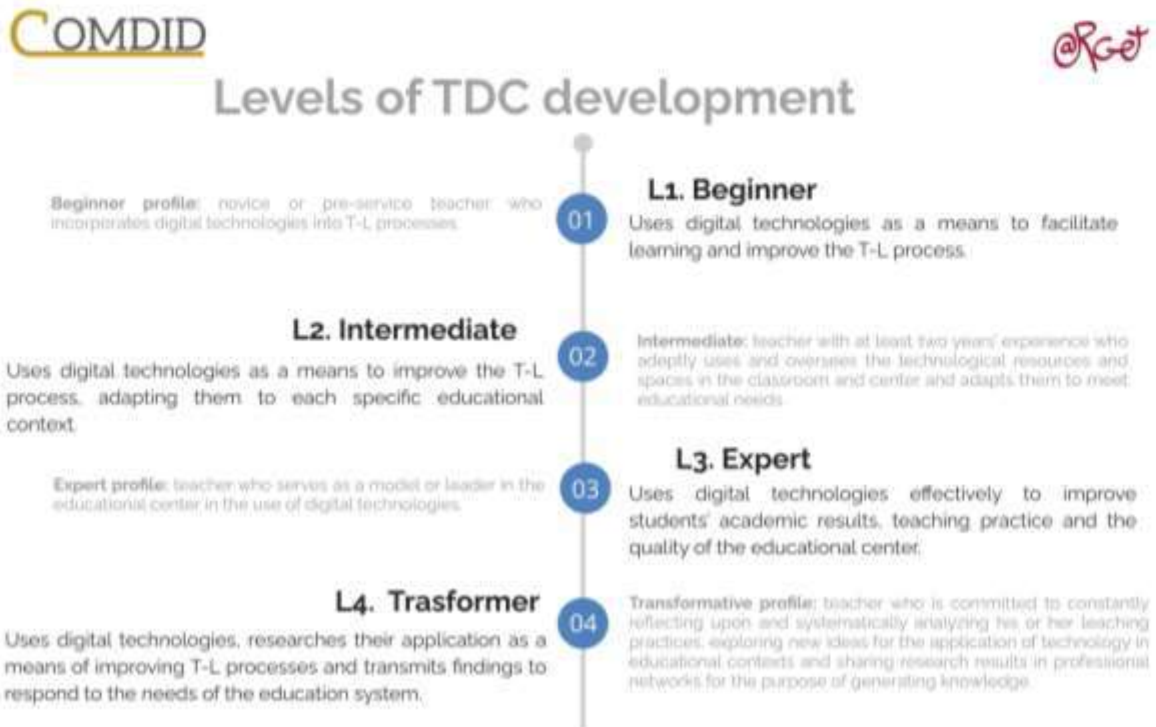
Figure 1

TDC dimensions and descriptors in the COMDID A model

Source: ARGET Research Group, Universitat Rovira i Virgili

The questionnaire is based on an evaluative scale with five response options, reflected in a scoring continuum with gradations at 0, 25, 50, 75, and 100. This structured scale facilitates a nuanced appraisal of each indicator, calibrated against its developmental progression. Figure 2 shows an expanded description of this categorization framework and the operationalization of the evaluative scale.

Figure 2
TDC levels of development



Source: ARGET Research Group, Universitat Rovira i Virgili.

Reliability and validation of the COMDID-A instrument

The instrument's reliability was verified with Cronbach's alpha coefficient (Cronbach, 1951). A factorial confirmatory analysis (FCA) was also applied in accordance with the methodological guidelines for its use (López-Aguado & Gutiérrez-Provecho, 2019).

Data analysis

Our data analysis process consisted of a two-pronged analytical approach that incorporated both descriptive and inferential statistical techniques performed with IBM SPSS statistics software (Version 28.0.1.1.15). The initial analytical phase attempted to detect central tendencies and dispersion metrics within the collected data, aiming to construct a foundational quantitative level of TDC among the faculty at UNACH in Ecuador. After the preliminary analysis, a phase of inferential statistical examination was begun using Spearman's Rho as a pivotal tool to determine potential associative dynamics among the variables of interest: the domain of knowledge corresponding to the subjects' undergraduate and graduate qualifications, their academic department affiliation, academic program, employment status, and the attainment of doctoral-level education. Throughout the analysis, a suite of statistical metrics including correlation coefficients, statistical significance (Sig.), effect size (p), and statistical power (1-β) were assessed using Gpower software (version 3.1.9.6) (Erdfelder et al., 1996; Faul et al., 2007).

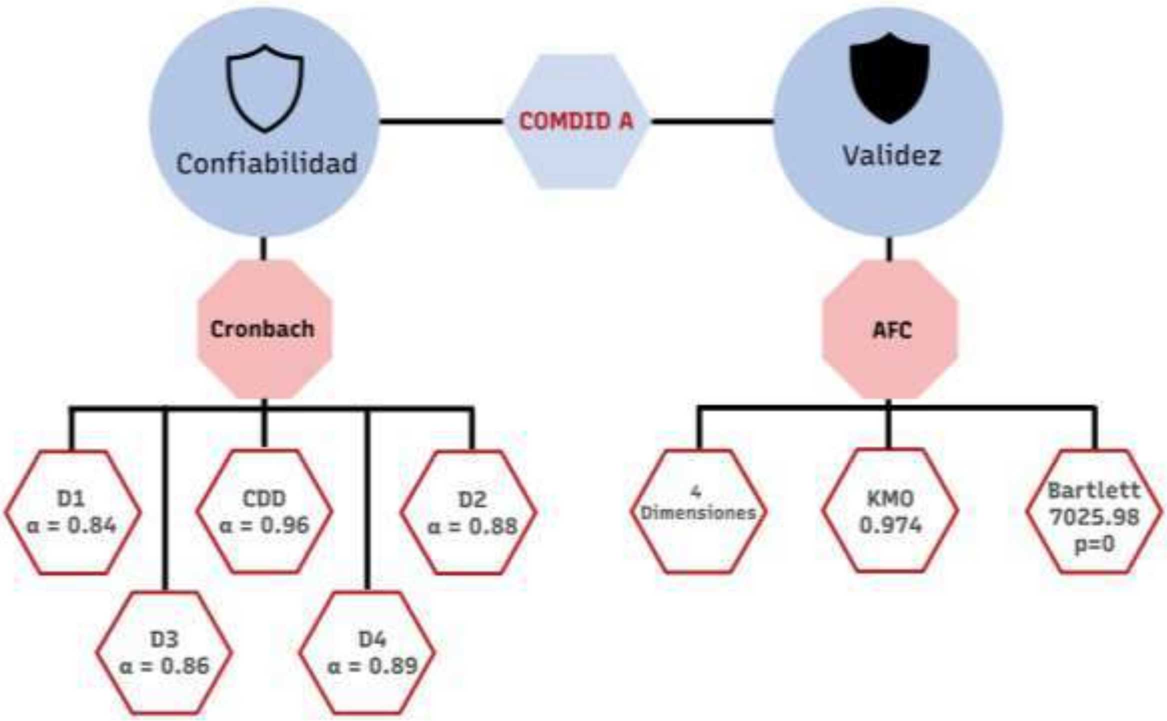
To further examine the intricacies of TDC, a factor analysis was applied with two fixed components: employment relationship and academic program. This analytical stratagem was chosen to detect any substantive effects exerted by these variables on levels of TDC. To this end, we used a general linear model (ANOVA) with an F-statistic as a means of quantification (Garibaldi et al., 2019).

RESULTS

Instrument reliability and construct validity

The principal component analysis (PCA) showed that the sample exhibited optimal congruence with the Kaiser-Meyer-Olkin (KMO) metrics. Furthermore, the determination of four distinct factors, cumulatively accounting for 65 % of the variance, is consistent with the dimensions defined by the COMDID-A framework (Cisneros-Barahona, Marqués-Molías, Samaniego-Erazo, Mejía-Granizo & De la Cruz-Fernández, 2023). The computation of Cronbach's alpha across the entirety of the instrument and its constituent dimensions revealed exemplary internal consistency, thereby confirming the robustness of the measuring tool (Figure 3).

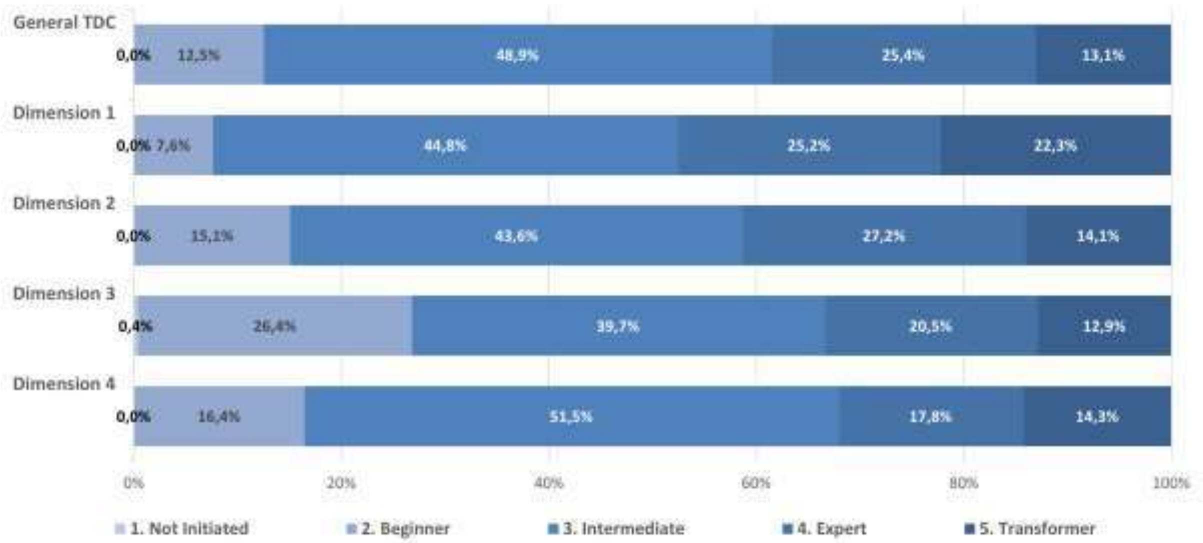
Figure 3
Reliability and validity of the COMDID-A instrument



Levels of TDC development

Figure 4 shows the TDC levels of the COMDID-A reference frame dimensions.

Figure 4
Teacher digital competence (TDC) proficiency across dimensional constructs



The representation of TDC levels, as framed by the COMDID-A reference structure, reveals a disparate distribution across the evaluated sample. Specifically, the "intermediate" and "expert" levels constitute approximately 49 % and 25 % of the sample, respectively, while the "beginner" and "transformer" levels are less prevalent, collectively representing about 13 %. Interestingly, there was a notable absence of educators within the "not initiated" category. Nevertheless, a nuanced examination across individual dimensions unveiled differing proficiency levels, signifying a diverse range of competences across the TDC spectrum.

Level of TDC development based on sample biodata

TDC in relation to area of knowledge of graduate-level degree

Figure 5 shows the analytical outcomes concerning TDC levels and the correlation of the disciplinary domains and the graduate qualifications of the professors at UNACH (República del Ecuador, 2023). A pervasive "intermediate" level of competence was observed across a broad spectrum of disciplinary fields, with prevalence rates oscillating between 33.33 % and 70.37 %. This distribution suggests that the educators at this institution have cultivated a moderate degree of proficiency in digital competences across diverse knowledge areas.

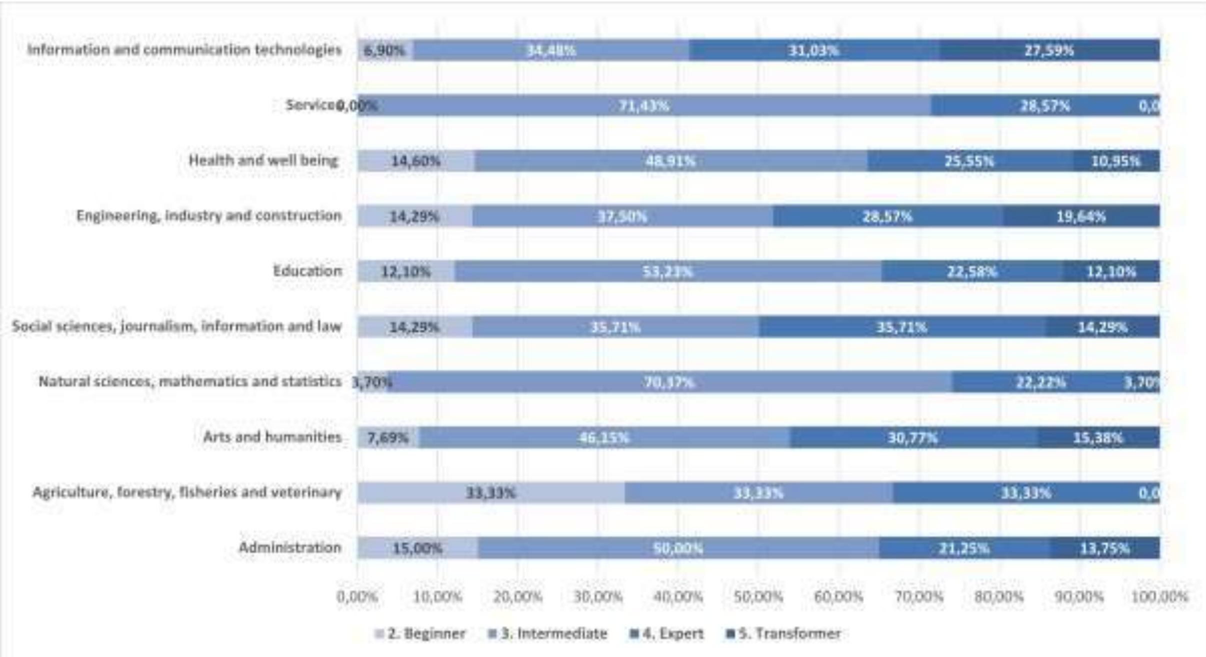
Conversely, the "transformer" level of TDC was less common, with incidences ranging from zero to 27.59 %. These findings point to a more infrequent integration of innovative pedagogical practices and technological applications within these disciplines.

It is noteworthy that disciplines such as agriculture, forestry, fisheries and veterinary sciences and services exhibited lower propensities towards the "transformer" level, indicating potential avenues for the enhancement of sophisticated digital skills within these fields. In contrast, 27.59 % of the subjects in the information and communication technologies domain scored at the "transformer" level, indicating the widespread adoption of educational technology innovations in that field.

A crucial observation was the absence of educators classified as "not initiated" across all fields of knowledge, signifying a foundational digital competency baseline among the faculty members. This revelation points to the ubiquitous presence of basic TDC across the academic landscape, setting a foundational platform for the further development of digital skills.

Figure 5

TDC levels in relation to area of knowledge of graduate-level degree



TDC in relation to area of knowledge of undergraduate-level degree

Figure 6 delineates the progression of TDC in juxtaposition with the disciplinary specialization of undergraduate degrees among faculty members at UNACH (República del Ecuador, 2023).

The prevalence of the "intermediate" competency level across diverse academic spheres, with figures oscillating between 38.46 % and 66.67 %, underscores a consistent trend towards moderate digital proficiency. Notably, this trend exhibits a spike at the "intermediate" level with an associated reduction across other competence levels, suggesting the pervasive acquisition of intermediate digital skills among the faculty.

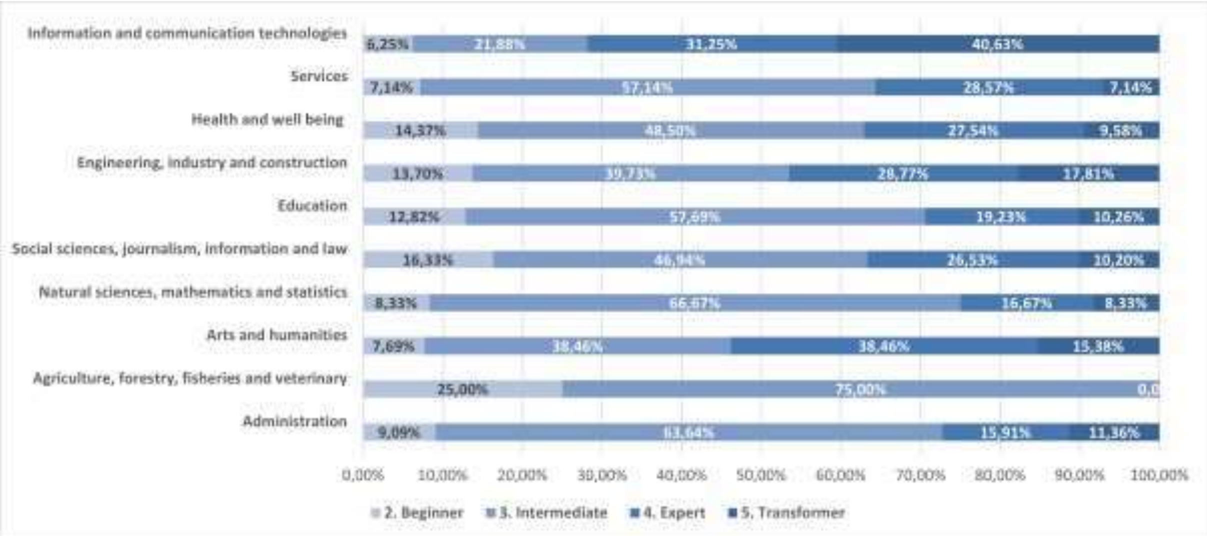
Prominently, the domains of information and communication technologies and engineering, industry, and construction were found to have high percentages of subjects at the "transformer" level, at 40.63 % and 17.81 % respectively, indicating a predilection towards innovative pedagogical and technological paradigms within these fields. Moreover, a significant contingent of educators within the fields of natural sciences, mathematics, and statistics (66.67 %) points to the overlapping relationship between these disciplines and the attainment of moderate DC.

Conversely, among subjects from the academic area of agriculture, forestry, fisheries, and veterinary sciences as well as from services, there was a conspicuous absence of scores at the “transformer” level, suggesting a potential gap in the advanced use of digital technologies. In this vein, strategies to foster a deeper integration of educational technologies within these sectors are imperative. Meanwhile, the information and communication technologies sector merge at the forefront, demonstrating a notable 40.63 % at the “transformer” level, indicative of its leadership in the adoption of cutting-edge DT in educational praxis.

The observation that no educators were categorized at the “not initiated” level across all disciplines is particularly salient, reflecting a universal baseline of digital competency among UNACH’s faculty.

Figure 6

TDC levels in relation to area of knowledge of undergraduate-level degree



TDC by department

Figure 7 shows the findings pertaining to the development of TDC by the specific academic departments to which the professors are affiliated.

At present, the organizational structure of UNACH encompasses four distinct academic departments:

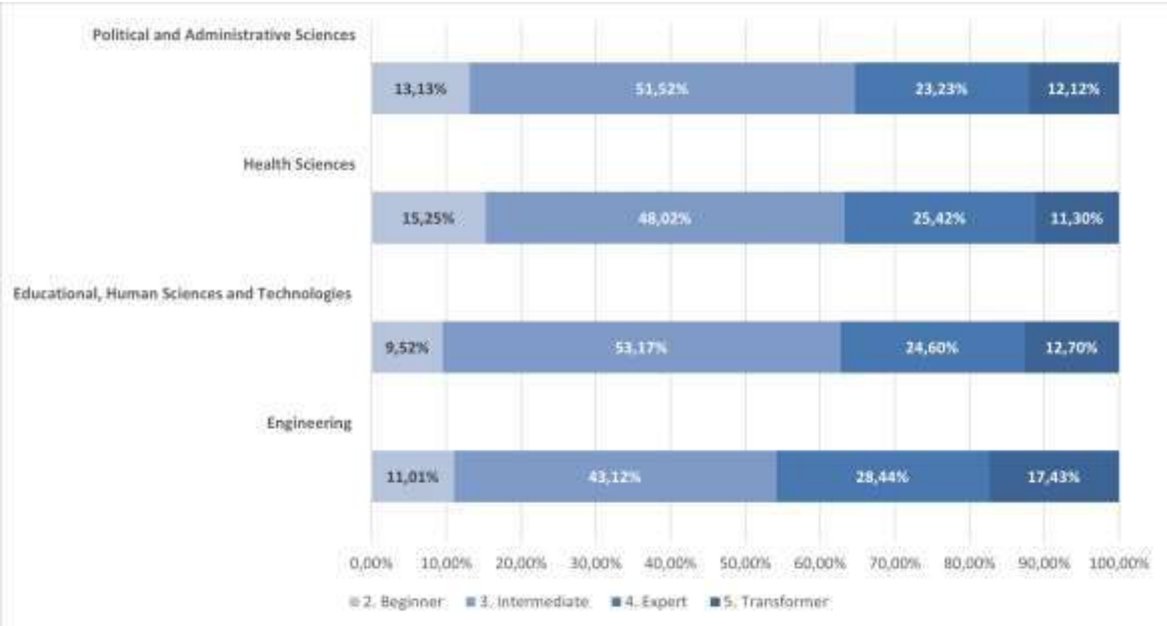
1. Department of Engineering (DE)
2. Department of Educational, Human Sciences and Technologies (DEHS&T)
3. Department of Health Sciences (DHS)
4. Department of Political and Administrative Sciences (DP&AS)

The educators affiliated with DEHS&T were found to have a predominant “intermediate” level of DC, with 53.17 % of staff members falling into this category. This is juxtaposed with a notably lower percentage of subjects at the “transformer” level (12.70 %). Conversely, the DHS exhibits a heightened proportion of faculty members at the "beginner" level (15.25 %), with a lesser representation at the "transformer" level (11.30 %). The DE and the DP&AS were found to have a relatively equitable distribution of DC across varying proficiency levels. Notably, the categorization of faculty members within the "not initiated" level across these departments was conspicuously absent.

The "intermediate" level of DC proficiency was found to prevail across all departments, followed sequentially by the "expert," "beginner," and "transformer" levels. This distribution suggests an inverse correlation between the level of DC and the prevalence of faculty members at the "transformer" level within each department.

Strategically customizing training and professional development initiatives, attentively calibrated to department-specific, discipline-oriented, and educational level considerations, promises to enhance their effectiveness. By ensuring tailored adjustments to the distinct needs and attributes of educators across diverse academic landscapes, DC enhancement efforts can be optimized.

Figure 7
TDC levels in relation to affiliated departments

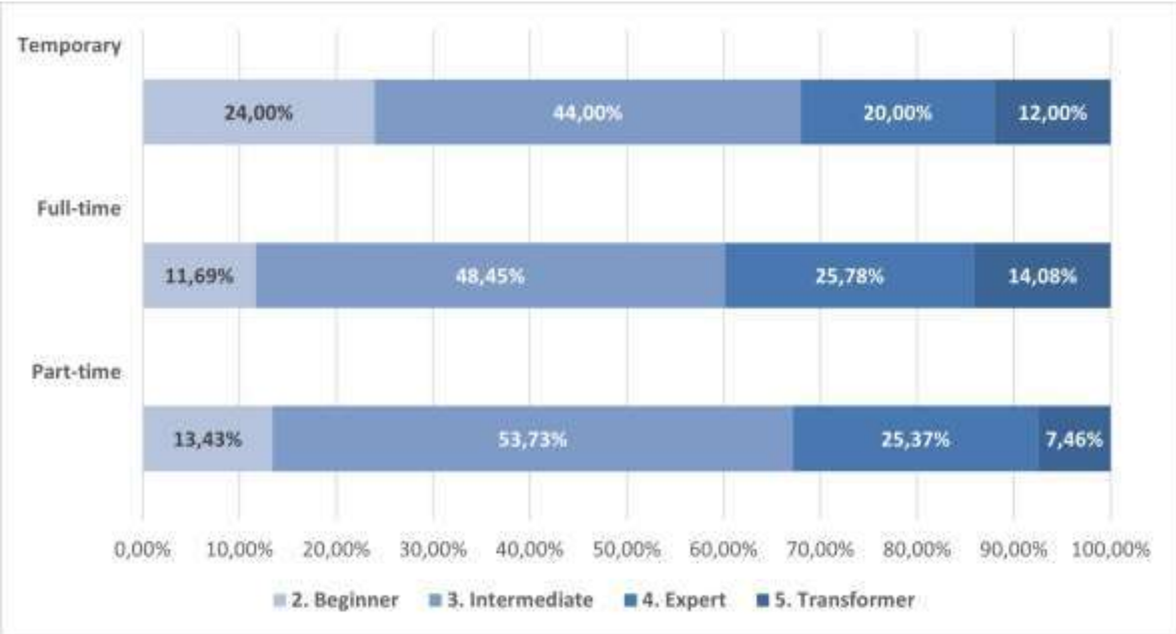


TDC in relation to employment status

Figure 8 shows the proportional distribution of TDC levels vis-à-vis the subjects' employment status, namely part-time, full-time, and temporary. Notably, the "intermediate" level of DC emerges as the predominant category across all employment status brackets. Nonetheless, it is worth emphasizing that the temporary and part-time statuses manifest comparatively higher incidences at the "transformer" level, with 12 % and 7.46 % respectively. This is in stark contrast to the full-time faculty, of which 14.08 % were ranked at this level. Additionally, a pronounced representation of educators at the "beginner" level (24 %) was found among teachers with temporary status.

The temporary and part-time employment status classifications stand out as having a higher proportion of faculty members at the "transformer" level. This pattern suggests that the reduced workload inherent to these employment statuses may provide these teachers with enhanced flexibility, thereby facilitating the integration of innovative pedagogical methods and technological practices in their educational processes.

Figure 8
TDC in relation to employment status



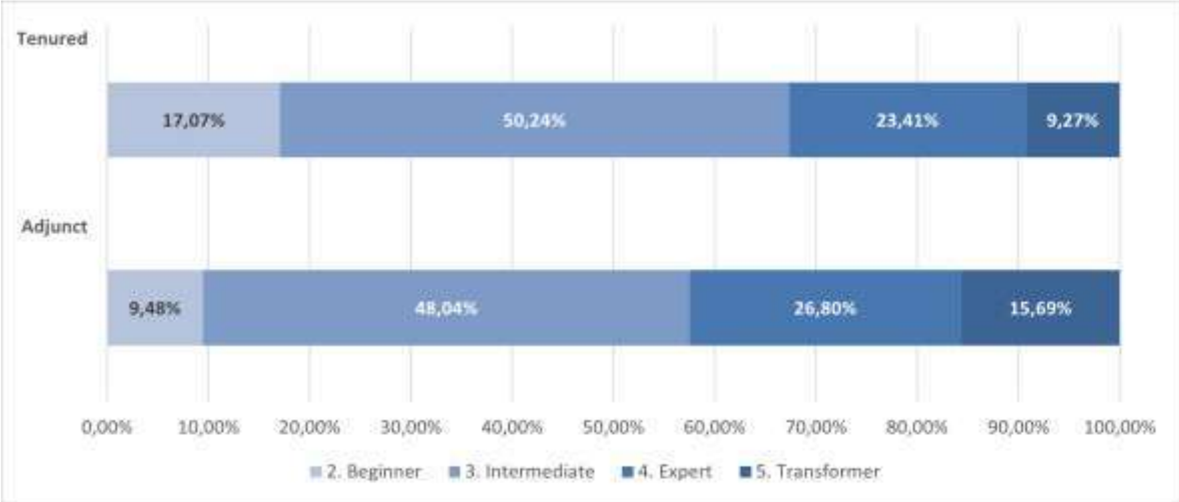
TDC in relation to employment relationship

Figure 9 shows the proportional distribution of TDC levels in relation to the employment status of the UNACH professors under study. Across the spectrum of employment categories, the “intermediate” level of TDC is consistently prominent, indicating a pervasive acquisition of DC within the academic context.

Particularly, we found a substantial number of professors with an “intermediate” level of TDC (50.24%) within the “full” (tenured) category. This prevalence suggests that tenured professors possess a foundational level of DC that is integral to their pedagogical functions. A similar trend was found among non-permanent teaching staff, with professors in the “adjunct” (non-permanent) employment category demonstrating a notable achievement of “intermediate” digital competences.

Overall, the “beginner” and “transformer” levels of TDC were found to be the least common, indicating a predilection for educators to attain either intermediate or advanced stages of DC.

Figure 9
TDC in relation to employment relationship

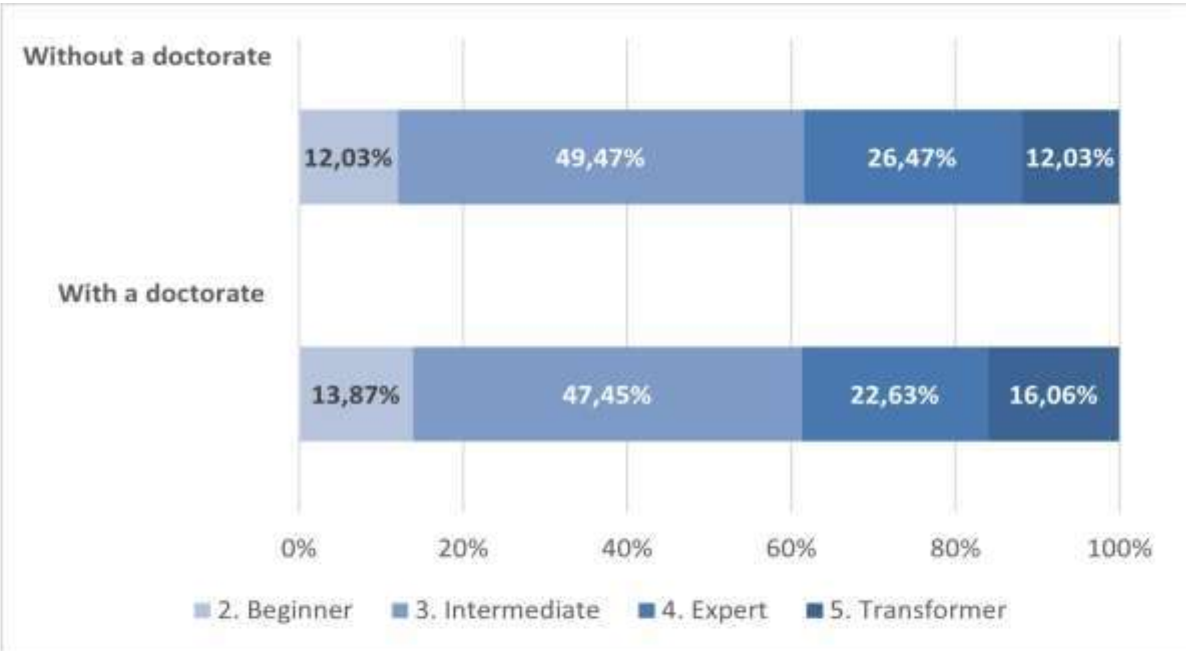


TDC in relation to possession of a doctoral degree

Figure 10 shows the proportional distribution of TDC levels vis-à-vis the attainment of doctoral qualifications among the faculty members of UNACH.

The comparative analysis reveals a notable parity at the "expert" level of TDC between professors holding doctoral degrees (22.63 %) and those without such qualifications (26.47 %). Notwithstanding, a discernible disparity emerges at the "transformer" level of TDC, with 16.06 % of educators holding doctorates documented at that level compared to 12.03 % among their counterparts without doctoral degrees.

Figure 10
TDC in relation to the possession of a doctoral degree



Correlational analysis

Given the non-normal distribution of the data pertinent to the variables examined, a non-parametric test was required for the correlation analyses. We chose the Spearman's Rho coefficient as the statistical measure (Creswell, 2011) due to the ordinal/nominal nature of the categorical variables. The correlation coefficients, statistical significance (Sig.), effect size (p), and statistical power (1-β) were also evaluated at the same time (Erdfelder et al., 1996).

Table 4 shows the interrelations between TDC and a range of variables pertinent to the faculty at UNACH (Creswell, 2011). The correlations observed were predominantly of a low magnitude. The analyses did not reveal any statistically significant associations between the variables of employment status or the disciplinary field of undergraduate- or graduate-level degrees and the level of TDC development.

Conversely, statistically significant correlations were discerned regarding department affiliation and academic program academic program. These findings suggest the potential impact of these variables on the cultivation of TDC. Furthermore, notable correlations were identified in relation to the possession of doctoral degrees, indicating a potential variation in TDC levels contingent upon the doctoral qualifications attained by educators.

Table 4

Correlations of TDC level at the item/dimension level with educational environment variables (n=511)

Variable	Spearman's Rho	D1	D2	D3	D4	TDC	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6	D2.1	D2.2	D2.3	D2.4	D2.5	D3.1	D3.2	D3.3	D3.4	D3.5	D4.1	D4.2	D4.3	D4.4	D4.5	D4.6
Area of knowledge of undergraduate-level degree	Coef.	.03	.02	.02	.00	.01	.03	.06	.02	-.03	.00	-.03	.03	.01	.00	-.02	.07	.00	.01	.04	-.02	.03	-.02	-.01	.00	.07	-.02	.03
	Sig.	.44	.60	.57	.99	.91	.52	.16	.67	.47	.94	.54	.53	.86	.94	.71	.14	.97	.77	.37	.66	.48	.63	.89	.99	.11	.62	.55
	ρ	.17	.14	.14	.03	.10	.17	.24	.14	.17	.03	.17	.17	.10	.03	.14	.26	.03	.10	.20	.14	.17	.14	.10	.03	.26	.14	.17
	1-β	.99	.99	.99	.99	.94	.87	.99	.99	.99	.94	.99	.87	.97	.95	.99	.99	.98	.98	.99	.99	.99	.99	.99	.99	.99	.99	.99
Area of knowledge of graduate-level degree	Coef.	.03	.01	.01	-.01	.00	.05	.06	.02	.03	-.02	-.01	.02	.00	-.04	.01	.05	.00	.01	.05	.00	.02	-.03	-.01	-.03	.05	-.04	.02
	Sig.	.52	.74	.87	.78	.98	.26	.17	.64	.55	.59	.89	.62	.96	.38	.90	.24	.98	.84	.31	.95	.69	.44	.84	.51	.27	.37	.62
	ρ	.17	.10	.10	.10	.03	.22	.24	.14	.17	.14	.10	.14	.03	.20	.10	.22	.03	.10	.22	.03	.14	.17	.10	.17	.22	.20	.14
	1-β	.99	.98	.99	.98	.99	.99	.99	.99	.99	.99	.99	.99	.97	.99	.99	.99	.99	.99	.99	.96	.99	.99	.99	.99	.99	.99	.99
Department	Coef.	-.06	-.07	-.02	-.03	-.04	**-.09***	-.01	-.05	-.02	-.03	-.01	-.09	.01	-.04	-.02	**-.09***	-.01	-.03	.03	.01	-.05	.02	-.02	-.05	-.07	.02	-.04
	Sig.	.15	.14	.58	.46	.40	**.03**	.80	.28	.70	.54	.75	.05	.88	.34	.62	**.03**	.81	.47	.51	.88	.24	.69	.58	.29	.11	.64	.43
	ρ	.24	.26	.14	.17	.20	**.31**	.10	.22	.14	.17	.10	.30	.10	.20	.14	**.31**	.10	.17	.17	.10	.22	.14	.14	.22	.26	.14	.20
	1-β	.99	.99	.99	.99	.99	**1.00**	.98	.99	.99	.99	.98	.99	.99	.99	.99	**1.00**	.98	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99
Academic program	Coef.	-.07	-.07	-.03	-.03	-.05	**-.11***	.00	-.05	-.02	-.05	-.03	**-.09***	.00	-.05	-.03	**-.11***	-.02	-.03	.03	.01	-.06	.01	-.02	-.04	-.07	.01	-.04
	Sig.	.12	.11	.54	.57	.30	**.01**	.92	.22	.73	.30	.52	**.05**	.98	.26	.52	**.02**	.73	.46	.52	.86	.20	.74	.64	.40	.12	.76	.39
	ρ	.26	.26	.17	.17	.22	**.33**	.03	.22	.14	.22	.17	**.29**	.03	.22	.17	**.33**	.14	.17	.17	.10	.24	.10	.14	.20	.26	.10	.20
	1-β	.99	.99	.99	.99	.99	**1.00**	.94	.99	.99	.99	.99	**1.00**	.98	.99	.99	**1.00**	.99	.99	.99	.99	.99	.98	.99	.99	.99	.98	.99
Employment status	Coef.	.00	-.08	-.05	-.05	-.08	-.02	.03	-.03	-.01	-.05	-.08	-.05	-.05	**-.09***	-.08	-.03	-.04	.01	-.04	-.07	.01	-.05	-.01	-.03	-.06	-.01	.01
	Sig.	.99	.09	.31	.27	.09	.73	.51	.54	.83	.24	.07	.28	.24	**.04**	.08	.44	.32	.75	.33	.13	.83	.23	.77	.43	.18	.79	.85
	ρ	.03	.28	.22	.22	.28	.14	.17	.17	.10	.22	.28	.22	.22	**.30**	.28	.17	.20	.10	.20	.26	.10	.22	.10	.17	.24	.10	.10
	1-β	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	**1.00**	.99	.99	.99	.98	.99	.99	.99	.99	.98	.99	.99	.98	.99
Doctoral degree	Coef.	-.04	-.03	.02	-.05	.00	-.02	-.04	**-.09***	-.04	-.03	-.01	-.06	.00	-.01	-.06	-.02	.02	.06	.01	.00	-.03	-.05	-.02	-.04	-.02	-.01	.00
	Sig.	.37	.53	.63	.26	.92	.72	.39	**.04**	.36	.55	.83	.19	.96	.89	.19	.71	.69	.19	.77	.99	.44	.25	.60	.43	.68	.76	.95
	ρ	.20	.17	.14	.22	.03	.14	.20	**.30**	.20	.17	.10	.24	.03	.10	.24	.14	.14	.24	.10	.03	.17	.22	.14	.20	.14	.10	.03
	1-β	.99	.99	.99	.99	.94	.99	.99	**1.00**	.99	.99	.99	.99	.97	.99	.99	.99	.99	.99	.98	.99	.99	.99	.99	.99	.99	.98	.96

Note: *. The correlation is significant at the .05 (2-tailed) level; **. The correlation is significant at the .01 (2-tailed) level; ρ=.10 low, .30 medium, .50 high (Cohen, 1988); 1-β at least .80 to generalize the results (Cohen, 1992).

General linear model (ANOVA) between TDC and the fixed variables employment relationship and academic program

The modified Breusch-Pagan test (White's test) detected a discernible level of significance, corroborating the presence of heteroscedasticity within the sample. This indicates that the variance of the residuals does not maintain constancy across the spectrum of the predictor variables, namely employment relationship and academic program. Furthermore, the application of the Kolmogorov-Smirnov test for independent samples yielded significances surpassing the .05 threshold, thereby justifying the use of a general linear ANOVA model to analyze TDC based on the fixed factors of employment relationship and academic program.

This analysis sought to determine the impact of the variables employment relationship and academic program on level of TDC, including their interaction effects. The null hypothesis posits equality among the mean values of the designated populations for each factor, excluding the presence of interaction effects. The F statistic served as the analytical tool (Garibaldi et al., 2019).

Table 5 shows the test of between-subject effects. The subsequent ANOVA revealed discernible differences between the variables employment relationship and academic program and TDC level, at a significance threshold of .05. Moreover, the interaction effects, along with the intersection and the corrected model, were found to be statistically significant.

Table 5

Results of inter-subject effects, TDC and the fixed variables employment relationship and academic program

Dependent variable: TDC

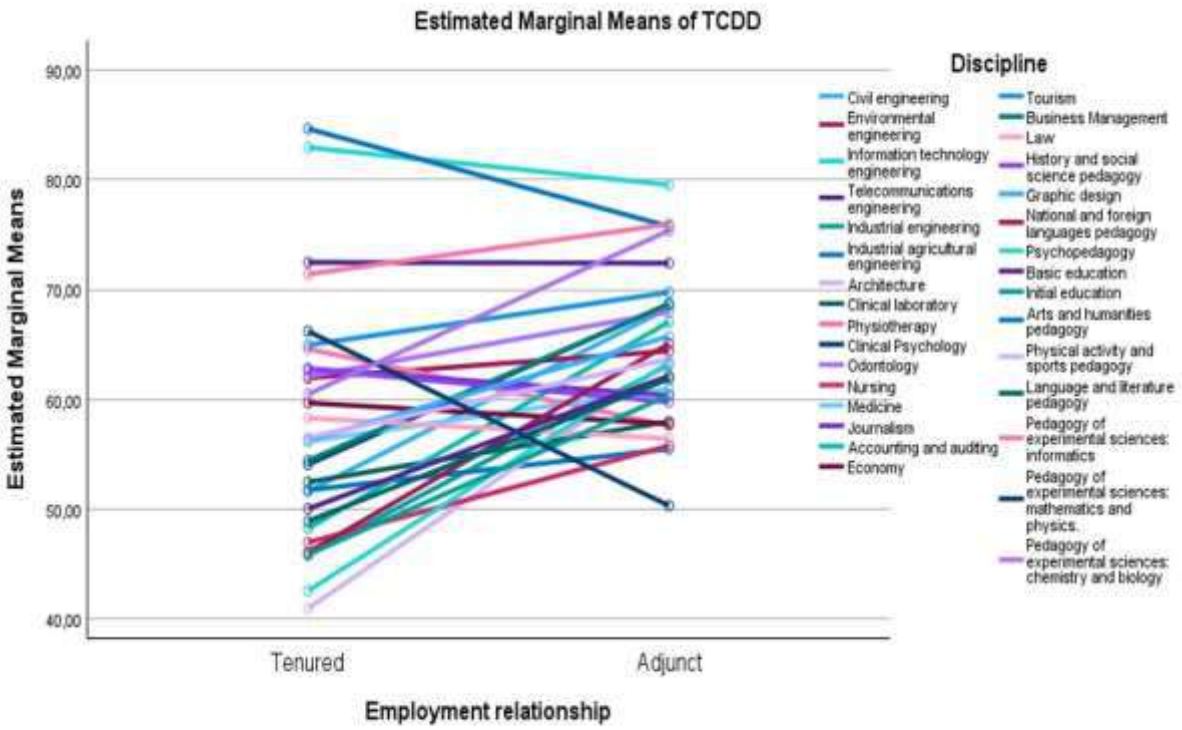
Origin	Type III sum of squares	df	Quadratic mean	F	Sig.	Partial Eta squared
Corrected model	64.922[a]	61	1.064	1.499	0.012	0.169
Intersection	4230.310	1	4230.310	5958.002	0.000	0.930
Employment relationship	6.705	1	6.705	9.444	0.002	0.021
Academic program	38.644	30	1.288	1.814	0.006	0.108
Employment relationship * Academic program	21.564	30	0.719	1.012	0.451	0.063
Error	318.800	449	0.710			
Total	6261.000	511				
Total corrected	383.722	510				

a. R squared =.169 (Adjusted R squared =.056)

The factor analysis, as illustrated in Figure 11, shows the marginal means of the levels of TDC in relation to the employment relationship of the educators studied and their respective academic programs within the university. Among the 31 academic programs examined, 23 exhibit statistically significant variances, revealing a perception of higher competence in adjunct professors compared to their tenured counterparts.

Figure 11

Indicators with the highest average score in relation to employment relationship and the dimensions of the COMDID-A framework (estimated marginal averages of TDC)



DISCUSSION AND CONCLUSIONS

The reliability of the instrument within the sampled demographic was confirmed by means of Cronbach's alpha.

A confirmatory factor analysis (CFA) served to refine the precision and validity of the constructs delineated by the COMDID-A framework, which improved the quality and empirical credibility of the research outcomes. The alignment of the proposed structural construct with the sampled data validated the interrelation between the theoretical model and the empirical items. Moreover, the establishment of a coherent dimensional structure, characterized by substantial correlations among the dimensions, further corroborated the instrument's internal consistency.

Understanding the interrelationships within the correlation matrix is instrumental in deciphering the complex dynamics of the COMDID-A model. The evidence of convergent validity improved the coherence among variables within identical dimensions, whereas discriminant validity distinctly separated the dimensions from one another. The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test outcomes substantiate the CFA's appropriateness, revealing a significant underlying structure within the data. The presence of moderately high communalities suggests that the derived factors are intimately linked to the observed variables, thereby reinforcing the model's overarching validity.

Echoing prior research that made use of the COMDID-A rubric, in our study, Dimension 1 exhibited a more advanced level of development (Palau et al., 2019; Paz Saavedra & Gisbert Cervera, 2023). Conversely, while preceding studies have accentuated the integrity of Dimension 3 (Lázaro-Cantabrana et al., 2019; Silva et al., 2019), our research found a diminished mean rating within this domain. Variations such as these clearly reflect the contextual and demographic specificities inherent to the study.

The prevailing "intermediate" level of TDC across all evaluated dimensions is consistent with the corpus of existing literature (Santos et al., 2021). Nevertheless, the fact that not even 50 % of the subjects surpassed that competency level is noteworthy. Moreover, a minimal contingent of educators fell into the "not initiated" level within Dimension 3, and that lowest level was completely absent in Dimensions 1, 2, and 4. These patterns indicate that most teachers possess moderate digital skills, while drawing attention to a niche demographic yet to embark on their TDC development, particularly within Dimension 3. These results emphasize the importance of a call to action for intensified focus and investment in competence development initiatives aimed at elevating DT and DC mastery within academia.

In alignment with the overarching trends detected in relation to TDC levels, the "intermediate" level was found to be prevalent across most indicators within Dimension 1. Notably, the "not initiated" level was minimally represented across all indicators, suggesting an elemental familiarity amongst educators with DT and their pedagogical applications. Certain indicators, notably "1.1. Teacher planning and digital competence" and "1.3. Data processing and knowledge creation", were found to have a significant contingent at the "expert" and "transformer" levels, indicative of advanced proficiencies in instructional planning and the use of digital information for knowledge generation. Conversely, the indicator "1.2. Digital technologies as facilitators of learning" showed a prevalence of "beginner" level scores, signifying potential areas for pedagogical enhancement. Furthermore, "1.3. Data processing and knowledge creation" and "1.4. Attention to diversity" within Dimension 1, when evaluated at the "expert" and "transformer" levels, underscore a symbiotic relationship between these domains and elevated levels of TDC. These observations are congruent with scholarly assertions advocating for comprehensive training in DT and curriculum integration, particularly emphasizing improved pedagogical competences which occasionally manifest suboptimal levels in contrast to other dimensions (Ayale-Pérez & Joo-Nagata, 2019; Lago Martínez et al., 2017).

The analysis of Dimension 2 revealed a pronounced proficiency at the "expert" and "transformer" levels within the "2.1 Learning environments" and "2.2 Managing digital technologies and programming" indicators, denoting advanced competences. Conversely, "2.3 Spaces with digital technologies of the educational center" exhibited a notable presence of "beginner" and "intermediate" level teachers, pointing to avenues for capacity development and reinforcement.

Dimension 3 consistently exhibited distributions across the "intermediate" and "beginner" levels, with "expert" and "transformer" levels also present, albeit less prominently. The "3.4 Digital content and the educational community" indicator is particularly noteworthy for its diverse distribution across the "beginner", "intermediate", and "expert" levels, highlighting a concerted focus on generating apt digital content. These parallel findings suggesting that ethical dimensions, such as "3.1 Ethics and safety", are often documented at lower competency levels (Arango et al., 2020; Gallego-Arrufat et al., 2019).

Additionally, both "3.3 Communication, dissemination and transfer of knowledge" in Dimension 3, and "4.5 Personal learning environment (PLE)" in Dimension 4, were identified with diminished levels of TDC, which is consistent with the findings of other researchers (Basantes-Andrade et al., 2020; Biel & Ramos, 2019; Cabero-Almenara et al., 2021; Gutiérrez-Castillo et al., 2017). This accentuates the imperative for curating training modalities aimed at improving TDC levels, confronting the pedagogical exigencies emergent when DT and DC are not integrally woven into the teaching and learning (T-L) schema (Romero-Tena et al., 2020; Wu, 2014; Zhao et al., 2019).

Within Dimension 4, the indicators “4.3 Lifelong learning” and “4.5 Personal learning environment (PLE)” are notably distinguished by a pronounced prevalence of “intermediate” and “expert” levels. Specifically, “4.3 Lifelong learning” is characterized by elevated proportions of “experts” and “transformers”, reflecting a strategic emphasis on continuing professional development and the cultivation of personal learning environments at an institutional scale.

These findings are congruent with those in the published literature and underscore the nuanced variability of TDC across disparate cohorts of educational professionals (Zhao et al., 2021). Such distinctions are pivotal for contextualizing TDC evaluations amidst the evolving complexities and heterogeneity inherent to contemporary educational landscapes.

The marked disparities between groups highlights the instrumental role of DT in the configuration of educators’ DC (Guillén-Gámez et al., 2021), which strengthens the imperative to incorporate these factors into the framework of professional development initiatives aimed at improving TDC (Amhag et al., 2019; Nascimbeni, 2020). The tailoring and customization of these interventions are deemed crucial for bridging the competence gaps identified in this work and fostering the equitable ascension of DC within the educational community (Juárez Arall & Marqués Molías, 2019; Silva Quiroz, 2017).

The use of Spearman’s Rho to ascertain correlation coefficients brought to light significant positive correlations between TDC as a whole and its constituent dimensions (D1, D2, D3, D4), in agreement with prior research findings (Cabrera, 2009; Reguant-Álvarez et al., 2018). This interconnection reinforces the assertion that advancements within a singular dimension invariably precipitate beneficial impacts across the TDC spectrum, thereby fostering a multifaceted skills profile. Such a pattern of synergy and mutual reinforcement among the various facets of TDC aligns with other observations within the Latin American educational context (Paz Saavedra & Gisbert Cervera, 2023)

These interdimensional dynamics offer profound insight into the integrative essence of TDC (Gutiérrez-Castillo et al., 2017). Acknowledging that progression in one dimension catalyzes advancements in others underscores the need for holistic approaches in the design and execution of training and professional development programs (Garita-González et al., 2019). This comprehensive viewpoint is indispensable for navigating the intricacies of TDC and ensuring the balanced development of skills (Biel & Ramos, 2019; Vallejo & Aguayo, 2021).

The coherence observed amongst competency levels across dimensions indicates that the enhancement of digital skills transcends specific domains, fostering an effective interdimensional transfer and integration of DC. This pattern strengthens the argument for the holistic development of such competences (Romero-Tena et al., 2020), as the consistent skill levels across the diverse dimensions attest to the depth and scope of the DC profile cultivated within the subject group (Santos et al., 2021).

Exploring the diversity of correlations sheds light on the multifaceted nature of TDC and underscores its inherent complexity (Gisbert Cervera & Esteve Mon, 2011).

The absence of definitive patterns in its development suggests the convergence of several subtly interacting factors, thus highlighting the intricate and individualized journey educators embark on in acquiring DC (Fernández Sánchez et al., 2016; Padilla-Hernández et al., 2020).

The negligible correlations with educators' fields of study at both the undergraduate and graduate levels, as well as their employment relationship, suggest that these variables may not significantly sway TDC levels within this study's context. Understanding these complex and indirect correlations is pivotal in formulating professional development strategies and educational policies, demonstrating the need for interventions tailored to educators' unique contextual and educational requirements (Cisneros-Barahona, Marqués-Molías, Samaniego-Erazo & Mejía-Granizo, 2023).

Notably, the discernible correlations with departmental affiliation and academic program underscore the impact of structured programs on the various levels of TDC observed (González et al., 2020). This finding accentuates the role of the academic context in shaping educators' DC, emphasizing the importance of integrating these elements into the design of targeted training and intervention strategies.

Moreover, the correlation with doctoral qualifications underscores the critical role of academic attainment in TDC (Sarango Lapo, 2021). This correlation suggests a propensity among more highly educated educators towards advanced DC, thereby linking educational achievement with the acquisition of sophisticated digital skills and highlighting the value of promoting academic progression as part of TDC enhancement initiatives (Amhag et al., 2019; Gutiérrez-Castillo et al., 2017).

The linear factor analysis indicated statistically significant variances, revealing that adjunct professors are often perceived as more digitally competent than their tenured counterparts, a finding which diverges from other studies suggesting the opposite (Rodríguez Espinosa, 2016). This discrepancy invites further inquiry into training modalities, exposure to digital educational technologies, and opportunities for professional development, potentially elucidating the underlying causes for these observed differences.

These insights not only contribute to a nuanced understanding of TDC within the examined context but also establish a foundation for future research and informed educational policymaking. Recognizing variables associated with DT enhances the precision of TDC assessments and accentuates the need for strategic, personalized approaches to effectively improve DC among educators. Furthermore, employing advanced data analysis techniques (Cisneros-Barahona et al., 2021; Uvidia Fassler et al., 2017; Uvidia Fassler et al., 2018; Uvidia Fassler et al., 2019; Uvidia Fassler et al., 2020) to explore the reciprocal influences among competences across different dimensions could provide a more comprehensive understanding of the interrelations among skills, thereby enriching the overall conceptualization of TDC.

Data availability

The data used for the experimental replication is available at the following link: https://zenodo.org/doi/10.5281/zenodo.10655922

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Design and usability of IndagApp: an app for inquiry-based science education

Diseño y usabilidad de IndagApp: una app para la enseñanza de las ciencias por indagación

Iraya Yánez-Pérez - *Universidad de Burgos, UBU (Spain)*
Radu Bogdan Toma - *Universidad de Burgos, UBU (Spain)*
Jesús Ángel Meneses-Villagrá - *Universidad de Burgos, UBU (Spain)*

ABSTRACT

Inquiry is a didactic methodology that promotes the development of scientific competencies and the meaningful learning of science. However, its implementation in the Spanish educational context faces various barriers, such as the lack of both resources and teacher training. The objective of this study was to design and evaluate the usability of IndagApp; an ICT resource that facilitates the teaching of science by inquiry with students aged 10 to 14. A convergent mixed methods design was used, with an intentional sampling composed of a panel of 14 experts from different disciplines. The quantitative results showed high usability of the app, while the qualitative ones allowed for improving the user interface, including scaffolding strategies and aligning the resource with the curricular demands. From this process, an improvement of the app was made, which in its improved version consists of ten inquiries that address the central contents of the new LOMLOE curriculum. In addition, support resources have been designed for its implementation, such as guide programs for teachers and printable class sheets for students. Taken together, this resource is relevant and innovative for the didactic transposition of inquiry, providing the Ibero-American educational and research community with a valuable tool for the teaching of science. Future research delving into the usage and perceived usability among potential users in Primary and Secondary Education is warranted.

Keywords: simulation-based learning; mobile learning; educational app; virtual labs; scientific inquiry.

RESUMEN

La indagación es una metodología didáctica que promueve el desarrollo de competencias científicas y el aprendizaje significativo de las ciencias. Sin embargo, su implementación en el contexto educativo español se enfrenta a diversas barreras, como la falta de recursos y formación docente. El objetivo de este estudio fue diseñar y evaluar la usabilidad de IndagApp, un recurso TIC que facilita la enseñanza de las ciencias por indagación con alumnado de 10 a 14 años de edad. Se utilizó un diseño de métodos mixtos convergentes, con un muestreo intencional compuesto por un panel de 14 expertos de distintas disciplinas. Los resultados cuantitativos mostraron una usabilidad elevada de la app, mientras que los cualitativos permitieron mejorar la interfaz del usuario, incluir estrategias de andamiaje y alinear el recurso con las demandas curriculares. A partir de este proceso se realizó una mejora de la app que, en su versión mejorada, consta de diez indagaciones que abordan contenidos centrales del nuevo currículo de la LOMLOE. Además, se han diseñado recursos de apoyo para su implementación, como programas-guía para el profesorado y fichas de clase imprimibles para el alumnado. En conjunto, este recurso se presenta como pertinente e innovador para la transposición didáctica de la indagación, brindando a la comunidad educativa e investigadora iberoamericana una herramienta valiosa para la enseñanza de las ciencias. Se propone el desarrollo de investigaciones que aborden el análisis del uso y la percepción de la usabilidad del recurso en potenciales usuarios del ámbito de la Educación Primaria y Secundaria.

Palabras clave: aprendizaje basado en simulación; aprendizaje móvil; app educativa; laboratorios virtuales; indagación científica.

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INTRODUCTION

Inquiry-based teaching plays a pivotal role in science education worldwide, including in Spain (Morales et al., 2018; Schwartz et al., 2023). Inquiry-based teaching diverges from traditional methods focused on the explicit transmission of concepts and facts, as it promotes active learning that encourages students to explore and discover these concepts through scientific practices (Aditomo & Klieme, 2020; Alzate & Guevara, 2021; Toma, 2022). The inquiry methodology emphasizes critical thinking, problem-solving, and experimentation (Akerson & Bartels, 2023; Teig et al., 2022). The goal of this methodology is to cultivate a deeper understanding of scientific principles and foster students' scientific literacy (García-Carmona, 2020; Romero-Ariza, 2017). However, successfully implementing inquiry is challenging due to time and classroom management issues, resource scarcity, and teachers' lack of pedagogical content knowledge (Baroudi & Helder, 2019; Chichekian et al., 2016; Romero-Ariza et al., 2019). One of the main obstacles to its adoption is the lack of materials and educational kits specifically designed for inquiry-based science education (Fang, 2020). Furthermore, the availability and accessibility of necessary resources, such as laboratory equipment and materials, may be limited, further complicating the implementation of inquiry-based practices (Zhang, 2016).

In light of this context, this article presents the design, development, and usability evaluation of IndagApp. This educational app aims to address and reduce the barriers faced by teachers when implementing inquiry in science education. The project seeks to develop a practical solution that empowers teachers to effectively adopt this pedagogical strategy for teaching science. The objective is to provide a resource that is easily accessible and promotes teaching and learning practices that have been increasingly demanded by Ibero-American curricula in general (Morales et al., 2018; 2022), and Spanish curricula in particular (Criado et al., 2014; LOMLOE, 2020). This endeavor is supported by research in science education (Aguilera & Perales-Palacios, 2020; Lazonder & Harmsen, 2016; Romero-Ariza, 2017; Savelsbergh et al., 2016).

THEORETICAL UNDERPINNINGS

Inquiry-based science teaching

For decades, scientific inquiry has been subject to various interpretations and conceptualizations (Vorholzer & von Aufschnaiter, 2019). Consequently, despite the popularity of inquiry-based pedagogies, there is no single approach to its didactic transposition. According to Crawford (2014) and Schwartz et al. (2023), there are different ways to engage students in scientific inquiries, such as project-based learning, citizen science, or model-based inquiry, among others. However, the different conceptualizations of inquiry-based science education share common aspects: they address a central problem, use experimental procedures for data collection, and aim to develop evidence-based conclusions (Osborne, 2014; Pedaste et al., 2015; Toma, 2021a). Therefore, although there are several interpretations and definitions of inquiry, its pedagogical use implies that students emulate the work of scientists. This includes practices such as formulating research questions, designing and conducting experiments, analyzing data, and drawing conclusions (Crawford, 2014; García-Carmona, 2020; Schwartz et al., 2023).

Pedaste et al. (2015) proposed several inquiry cycles to facilitate the didactic transposition of this methodology. These usually comprise five interrelated and cyclical phases: orientation, conceptualization, investigation, conclusion, and discussion. This cycle assists both teachers and students in formulating questions and hypotheses, proposing experimental designs, collecting and analyzing data, and effectively communicating results (Rönnebeck et al., 2016; Vorholzer & von Aufschnaiter, 2019). Furthermore, it is common to use a continuum to categorize the types of inquiry units according to the scaffolding or assistance provided by the teacher (Fang et al., 2016; Schwartz et al., 2023). At the lowest level is confirmatory inquiry, resembling cookbook-style practical activities where students merely confirm a scientific phenomenon whose answer they already know. Next is structured inquiry, where the teacher determines the research question and procedure to follow, and support strategies are employed; however, students are unaware of the expected outcomes. In guided inquiry, students develop a procedure to answer a question provided by the teacher, the results of which they also do not know. Finally, at the top of the continuum lies open inquiry, where students pursue self-directed investigations with minimal teacher assistance or support.

In Spain, literature on the use of inquiry is flourishing, both in formal and informal education (Alarcón-Orozco et al., 2022; Alzate & Guevara, 2021; Morales et al., 2018, 2022). Furthermore, inquiry has been promoted in both previous (LOE, 2006; LOMCE, 2013) and current (LOMLOE, 2020) curricula. Specifically, the curriculum establishes a common block in the Primary Education stage, called "Scientific Culture", which aims to introduce students to scientific activity so that they develop skills and strategies of scientific thinking through research. Thus, the contents of this block emphasize the impact of science on our society (Royal Decree 157/2022).

ICT for science teaching

The importance of Information and Communication Technologies (ICT) in science education has increased in recent years. Recent research indicates that computers and tablets are effective for teaching and learning science. Indeed, in their systematic literature review, Scalise et al. (2011) concluded that virtual laboratories and simulations could enhance the learning of scientific concepts. Similarly, after reviewing 61 empirical studies, Smetana and Bell (2012) found that computational simulations are effective for teaching sciences and may be more effective than traditional classes and textbooks in promoting conceptual change and skill development. The literature also highlights several advantages of using virtual laboratories: they reduce the cost of equipment and materials, are accessible anytime and anywhere, the learning outcomes are similar to those of traditional practical laboratories, and they allow for the development of practical skills through experimentation (Ali et al., 2022; Aljuhani et al., 2018; Silva-Díaz et al., 2022).

Currently, there are several resources with virtual simulations, such as PhET Colorado and ChemCollective. The use of these tools by teachers has shown favorable results in primary (Bozzo et al., 2022), secondary (Bravo et al., 2019), and university students (Roll et al., 2018). However, these resources may resemble confirmatory inquiries or cookbook-style laboratory practices that involve following instructions to confirm a phenomenon. Additionally, these resources have limitations in that they are decontextualized from a problematic situation and omit the phases of authentic inquiry (Pedaste et al., 2015), such as formulating questions and hypotheses or identifying variables in the experiment, focusing mainly on the experimental simulation. Therefore, a resource is needed that addresses all stages of a scientific inquiry, which would assist teachers in adopting this teaching methodology and students in understanding scientific practices.

Usability evaluation of ICT resources

ICTs have a significant impact on both the learning experience and educational effectiveness (Silva-Díaz et al., 2022). For this reason, it is crucial to evaluate the perceived usability by users, which refers to the degree to which a system, product, or service can be used by users to achieve specific goals effectively, efficiently, and satisfactorily in a given context of use (ISO, 2018). In this regard, Vlachogianni and Tselios (2022) emphasized the importance of conducting usability studies to ensure that ICT resources are easy to use and designed to meet the needs of the target audience, which, in the case of this study, comprises primary and secondary school teachers.

The purpose of usability evaluation is to identify and address design and functionality issues. Research on the usability of educational technological resources usually focuses on three dimensions or constructs: effectiveness, efficiency, and user satisfaction (Lewis, 2018; Vlachogianni & Tselios, 2022). Effectiveness encompasses the user's ability to correctly complete a task using the resource. It includes aspects related to the perceived difficulty, ease of use, or whether different components (e.g., user interface, graphics, font) are adequately integrated (Del Rocio Sevilla-Gonzalez et al., 2020). On the other hand, efficiency is related to the extent to which the resource assists teachers in their teaching tasks (e.g., reducing class preparation time). As such, it is often measured through the perceived utility of the resource (Hoehle & Venkatesh, 2015). Finally, satisfaction refers to users' subjective reactions when using the resource. It includes aspects related to the affective rewards obtained through system adoption, such as enjoyment, increased self-efficacy, or interest (O'Brien et al., 2018).

DESCRIPTION OF INDAGAPP

IndagApp (in English, InquiryApp) is a 3D app designed to implement inquiry-based science teaching with students aged 10 to 14 years old (screenshots of the interface are provided in the Results section). In Spain, these ages correspond to the 5th and 6th grades of Primary Education and the 1st and 2nd grades of Secondary Education. IndagApp consists of a total of ten inquiry units that address different phenomena based on the core content of the Spanish LOMLOE educational law (2020; Real Decreto 157/2022): plant growth, crystal formation, forces, floods, bacterial growth, photosynthesis, buoyancy, valley formation, light refraction, and hot air balloon flight. IndagApp is available for smartphones and digital tablets with Android operating systems and for computers with Windows. Each investigation has a common structure and follows the principles and fundamental phases of scientific inquiry (Osborne, 2014; Pedaste et al., 2015; Schwartz et al., 2023). The inquiry cycle proposed by Pedaste et al. (2015) was adopted using terminology that is more accessible to teachers and students:

i. During the first phase of the inquiry unit, known as the phase of formulation of the problematic situation (orientation), students are guided to formulate specific and clear scientific questions about a natural phenomenon. All units begin with a contextualized learning situation that introduces the topic of study. The objective is for students to learn to ask precise and relevant questions that can be answered with an experimental design.

ii. In the second phase, known as hypothesis formulation (conceptualization), students formulate four tentative responses to the research question, so that each inquiry addresses four different hypotheses.

iii. In the third phase, called the planning and experimental design phase (investigation), students identify the dependent, independent, and control variables of the experimental design. These variables will later be used to test each of the hypotheses formulated.

iv. During the fourth phase, or data collection and interpretation (conclusion), students use specifically designed virtual simulations for each inquiry investigation, record the data in tables, and draw graphs. Subsequently, they interpret the data and respond to specific questions to search for patterns and possible explanations.

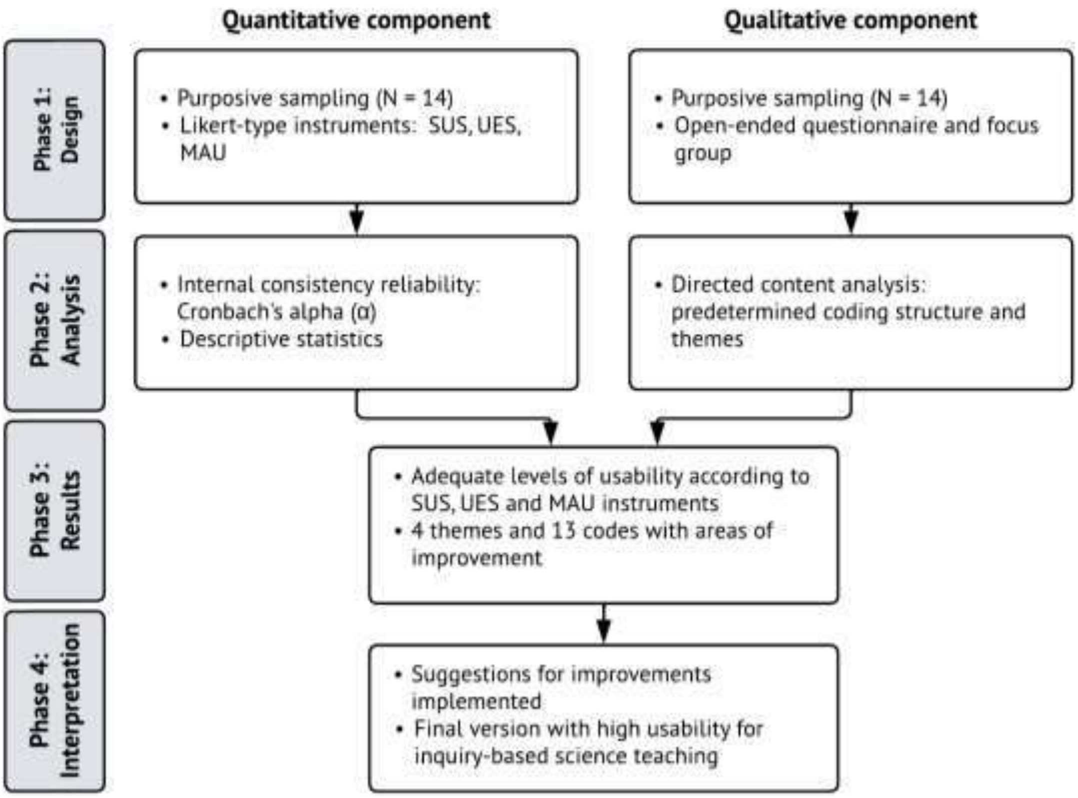
v. In the fifth and final phase, student understanding is assessed through consolidation and application of knowledge questions (discussion). This final phase tests students' ability to apply the concepts addressed in the inquiry unit to new problematic contexts.

METHODOLOGY

Research design

This study adopted a convergent mixed-methods research design, in which quantitative and qualitative components of the investigation are conducted separately during data collection (Creswell & Plano-Clark, 2018). The results are gathered independently and integrated or triangulated during interpretation (Figure 1).

Figure 1
Convergent mixed methods research design, based on Creswell and Plano-Clark (2018)



Sample

There is no specific sample size considered ideal for usability testing. Research indicates that most usability issues are detected with the first 3–5 subjects and that it is unlikely that more subjects will reveal new information (Nielsen et al., 2006). Typically, a study with 5 participants is sufficient to discover major problems and improve usability, and with 10 participants, more than 80% of usability problems are detected (Lewis, 2014).

Fourteen experts were recruited, six women and eight men, using purposive sampling techniques to ensure the inclusion of sources rich in information (Cohen et al., 2018). Nine of the experts are teaching and research staff at the University of Burgos and the University of Valladolid with expertise in the following areas and topics: Education Sciences and Inclusive Education, Didactics of Experimental Sciences –with training in the disciplines of physics, chemistry, biology, and geology– and Computer Engineering. Within this group, there was one Full Professor, two Associate Professors, two Assistant Professors, and two Lecturers with Ph.D. degrees, with an average professional experience of 23.3 years (min. = 7, max. = 40). Of the remaining experts, three were primary school teachers and two were secondary school teachers, with an average of 9.8 years (min. = 4, max. =16) of teaching experience.

Data collection instruments

For the quantitative component of this investigation, three instruments addressing the main dimensions of usability in educational research were used, employing a Likert-type scale (1 = Totally disagree; 5 = Totally agree). The first one was the *System Usability Scale* (SUS) questionnaire (Brooke, 1996), considered the gold standard for measuring subjective usability (Lewis, 2018). The questionnaire consists of 10 items that assess users' perceptions of the overall usability of IndagApp, such as "I consider IndagApp easy to use" and "I consider IndagApp unnecessarily complex". The version validated for use with the Spanish population was employed (Del Rocio Sevilla-Gonzalez et al., 2020). The Cronbach's alpha coefficient (α = .66) revealed marginal reliability, although consistent with previous research (Bangor et al., 2008; Vlachogianni & Tselios, 2022).

The second questionnaire, called the *User Engagement Scale* (UES) (O'Brien et al., 2018), consists of 12 items that measure four important dimensions complementing the SUS: focused attention (e.g., "The time I spent using IndagApp passed quickly"), perceived usability (e.g., "IndagApp seemed confusing to use"), aesthetic appeal (e.g., "IndagApp has a visually appealing design"), and reward factor, such as enjoyment or interest generated (e.g., "My experience with IndagApp was rewarding"). The Cronbach's alpha values indicate adequate reliability for all dimensions: α = .83, .70, .76, and .90.

The third questionnaire consists of the *Mobile Application Usability* (MAU) (Hoehle & Venkatesh, 2015), specifically designed and validated to evaluate the usability of apps. The MAU comprises 24 items measuring six different dimensions, including design (e.g., "I believe IndagApp has a good design"), utility (e.g., "I believe IndagApp is useful"), graphics (e.g., "The graphics of the IndagApp interface are well designed"), input (e.g., "IndagApp allows me to input data easily"), output from the user interface (e.g., "The content of IndagApp is presented effectively"), and structure (e.g., "IndagApp is very well structured"). The Cronbach's alpha coefficient showed very high reliability, with values of α = .92, .89, .96, .95, .94, and .86.

It should be noted that the UES and the MAU have not been previously validated in Spanish. Therefore, a cross-cultural translation procedure was used in this study, which required forward and back-translation procedures and a pilot test before data collection (Cohen et al., 2018).

On the other hand, for the qualitative component of the investigation, the participants conforming to the expert panel responded to a questionnaire with open-ended questions, which were discussed in two focus groups: the first with university faculty and the second with primary and secondary school teachers. The questionnaire was aligned with the usability dimensions measured during the quantitative component: ease of use (What difficulties have you experienced when using the app? How can the app be simplified to make it easier to use?), user experience (How can the different features of the app be better integrated?), user confidence/self-efficacy (What improvements can be implemented to increase user confidence/self-efficacy?), and intention to use (How can the app be designed to encourage frequent use?). A generic question was also formulated (Do you have any other suggestions to improve the performance, usability, and overall quality of the app?).

Data analysis

Descriptive statistics were used to analyze the quantitative data. The SUS scoring method involves subtracting 1 from odd-numbered items and subtracting the participant's score from 5 for even-numbered items. The resulting scores are then summed and multiplied by 2.5 to yield a score that ranges from 0 to 100. Scores equal to or above 68 indicate adequate usability (Brooke, 2013). For ease of interpretation, scores were next categorized on the adjective scale (Bangor et al., 2009): Worst imaginable (12.5), Awful (20.3), Poor (35.7), Fair (50.9), Good (71.4), Excellent (85.5), Best imaginable (90.9). For the UES and MAU instruments, the average of each dimension is calculated, with values close to one indicating very low usability and values close to five indicating very high usability.

Qualitative data were analyzed using a directed content analysis approach (Cohen et al., 2018). This analysis was grounded in usability dimensions from the literature, guided by a predetermined coding structure (Hoehle & Venkatesh, 2015; Lewis, 2014, 2018). It is noteworthy that in this study, all data were fitted to existing codes, and no instances requiring a new category were found.

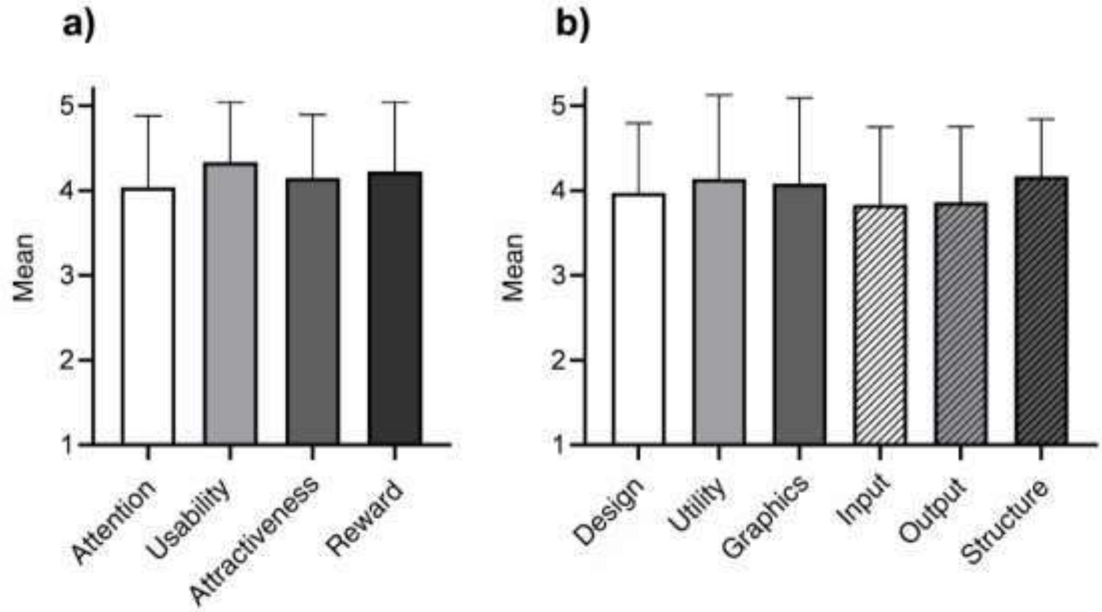
RESULTS

Quantitative component

Regarding the SUS, the average total score obtained was 80.89 (min. = 58, max. = 95; SD = 82.5), indicating a level of usability that securely surpasses the established minimum threshold. When analyzing the scores using Bangor et al.'s (2009) adjective scale, none of the experts rated usability as the worst imaginable, awful, or poor. Instead, two participants considered it fair, seven rated it as good, three considered it excellent, and two experts rated it as best imaginable.

As for the UES, the four evaluated dimensions revealed highly satisfactory responses (see Figure 2a). The average score exceeded 4 points out of 5 in all dimensions, with perceived usability particularly noteworthy. The dimension with the lowest results was the attention generated by the app, indicating potential avenues for improvement in terms of design and graphics. On the other hand, the six dimensions of the MAU also obtained high average scores (see Figure 2b). In this case, the highest scores were observed in the app's structural interface and the perceived utility of the resource, reaching scores above 4.1 out of 5 points. Conversely, the lowest scores were recorded in dimensions related to user interface input and output, suggesting areas for improvement in presenting the app's content.

Figure 2
Results for a) User Engagement Scale and b) Mobile Application Usability



Qualitative component

The results of the qualitative component of the investigation are next presented according to the following themes.

Theme #1. Ease of Use. Overall, participants perceived IndagApp as an easy-to-use resource. However, they pointed out several aspects that could be improved. The first of these is related to the lack of feedback and guidance during the use of the resource. Users expressed the need for instructions and explanations to understand the actions being carried out, especially when transitioning from one inquiry phase to another. Examples of comments include: "I had no idea what to do in some stages. Sometimes I could guess, but not always"; "If I were a student, I wouldn't know what to pay attention to or what data I need to complete the table in the next step"; "I would need some instructions to know what to do in each phase"; "I would like students to know what they are supposed to do in each phase"; or "Include explanatory text or audio that tells them the steps".

Another aspect of improvement related to the identification of variables during the methodological phase of the research. Specifically, there was a need for clearer instructions regarding the definition and identification of dependent, independent, and control variables. Users found it challenging to determine which variables were dependent, independent, and control. Examples of such comments include: "It is very difficult to determine which variables are dependent, independent, or control for each of the hypotheses. I think this will be very complicated for both students and teachers" and "It requires time and effort to understand these concepts, especially the first time you use the app".

Theme #2. User Experience. Participants' comments aimed at improving the user experience addressed aspects related to (i) error correction and stability, (ii) the duration of each inquiry, and (iii) the design and interface of the app. Regarding the first aspect, users encountered instances where the app would hang or freeze, as well as some issues related to content, such as errors when updating the results table. They mentioned instances such as: "It is necessary to resolve stability issues"; "Currently, the app is just a prototype and has several errors that need to be fixed to build trust and support the learning process"; "There are errors when updating the results table"; and "Review errors related to experiment results". Regarding the duration of each inquiry, users found it inconvenient to have to restart the entire experimentation and data collection phase each time they made a mistake when changing an independent or control variable, stating: "When I make a mistake and change a variable I shouldn't change, the experiment restarts completely, and the data from the table is lost. I have to start from scratch".

Regarding the design and interface of the app, experts suggested improving speed, agility, and graphics. They also recommended creating a version compatible with both computers and mobile devices. Another common improvement was to add a more age-appropriate interface for students. Comments included suggestions such as: "The graphics are not very appealing"; "Inquiry units should be a bit more engaging for students; they should be about topics that interest them at their age"; and "Improve the speed to make it a bit faster". Additionally, aspects related to interface design and structure were discussed for improvement. Suggestions included improving the accessibility of the button to advance to the next phase, the need for an exit button and a button to go back to the previous phase, and increasing the general font size, especially during data collection. Examples of these suggestions are: "The button to move from one phase to another should be in a more accessible location"; "Include an exit or close button; to close it, you have to force quit the application"; "There should be a button to go back [to previous phases]"; "The data in the tables are very difficult to read" or "The font is very small and hard to read".

Theme #3. User confidence. The panel of experts suggested including a user manual or tutorials to enhance self-efficacy in using the app. They asserted that having a supportive resource to guide teachers step-by-step through the inquiry process would improve their understanding and self-confidence in using the resource. They also expressed the need for explanations and instructions within the app to enhance understanding, both for teachers and students, of the purpose of each phase or task to be completed.

Theme #4. Intention to use. The experts mentioned that the use of the app could be encouraged by including a greater variety of inquiry units. They argued that having a wide range of units could increase their intention to use IndagApp to teach the science curriculum. Therefore, they recommended expanding the repertoire of inquiries related to the primary and secondary education curriculum. Some examples of comments include: "I miss more inquiry units", "I recommend developing more problems and learning situations to investigate", and "Inquiry units should be useful and serve to teach the content of the curriculum". Finally, they mentioned that it is important to improve and adapt the graphics to resemble games and common aesthetics for ages 10-14, as this could motivate students to use it more frequently.

Improvements implemented in the app

Table 1 shows the codes generated from the qualitative analysis, together with the improvements implemented in IndagApp based on the opinions and suggestions of the experts.

Table 1

Expert panel recommendations and improvements implemented

Criticism and recommendations from experts	Improvements implemented in IndagApp
Lack of feedback and instructions	Video tutorial on the inquiry process and a guided example. Help button provides explicit instructions for each phase.
Difficulty identifying variables	Video tutorial on types of variables and a guided example of their identification
Errors, frozen screen, lack of stability	Resolution of stability issues, errors, or frozen screens
Content errors	Correction of errors in the content of inquiries
Excessively long inquiry units	Shorter experimental simulations. Mistakes made while completing an inquiry do not delete progress but instead, display a warning to the user.
Slow app and simulations	Error correction improved app fluidity. Faster experimental simulations.
Improve and adapt graphics	Enhanced graphics tailored to the age of the target users (students aged 10 to 14)
Need to improve user engagement	New character that captures the user's attention and guides them through the inquiry
Develop a PC version	Development of a version available for PC (Windows), as well as for phones and tablets (Android)
Interface defects	Improved user interface: new design, 'exit' and 'go backward' buttons, better presentation of data, and larger font size
Tutorials are required	Development of user guides, with explanations for teachers and printable worksheets for students, hosted on the app's website
Develop new and diverse inquiry units	A total of ten inquiry units with varying levels of difficulty
Align inquiry units with the curriculum	Inquiry units rooted in the LOMLOE curriculum. Topics include physics, chemistry, biology, and geology for 5th and 6th grade of primary education and 1st and 2nd grade of secondary education.

Error correction and more attractive graphics. Various changes have been made to improve the user experience and increase their self-efficacy when using the app. Firstly, enhanced graphics tailored to the users' age group were created, and a main character was introduced to guide students and encourage their participation (Figure 3). Stability issues, errors, and failures in simulations were resolved, along with the correction of content errors, thus improving the accuracy and reliability of the presented scientific information. To shorten the duration of investigations, experimental simulations were redesigned, and data collection was modified so that errors did not affect progress; now, data is no longer erased, but a pop-up window appears to alert the user when an error is made. Similarly, design flaws were addressed through improvements in the user interface, such as the inclusion of exit and back buttons, revising navigation buttons, improving data presentation, and increasing font size (Figure 4).

Figure 3

Simulations of the inquiry units on a) Buoyancy and b) Crystallization. The image shows the new main character of each unit

a)

b)

Figure 4

The interface of a) the pilot version and b) the improved version of IndagApp. In the lower left margin of image b), one of the scaffolding menus can be seen

a)

b)

Scaffolding strategies. Scaffolding strategies have been implemented in IndagApp. These strategies are based on specialized literature on the adequate implementation of inquiry (Zacharia et al., 2015). This improvement addresses criticisms related to the lack of feedback and instructions. Now, such aspects are presented in text or video format. Each stage of the inquiry has a help button that provides explicit instructions for effective navigation. For example, in the third phase (planning and design), the steps for controlling and manipulating the variables are outlined. Regarding scaffolding in video format, two tutorials were created and added. The first provides a detailed summary of the inquiry process and each phase, following the phases proposed by Pedaste et al. (2015), while the second tutorial defines types of research variables and offers tips for identifying each one. Both tutorials include guided examples and are strategically placed in the main menu and at the beginning of the third phase of the inquiry unit. It is expected that the clear and concise presentation of this information will enable users to understand the key phases in the development of a scientific inquiry.

New inquiry units aligned with the curriculum. Ten scientific inquiries covering the core content of the LOMLOE (2020) science curriculum have been created. These inquiries have varying levels of difficulty and are available for download on Windows computers or mobile devices and tablets with Android. Both versions of the resource can now be downloaded for free via the Google Play Store (https://play.google.com/store/apps/details?id=com.ITACA.Indagapp). User manuals with instructions for teachers and printable class sheets for students have also been designed and are available on the project's website (http://www.webciencia.es/index.php/ind-virtual). These improvements aim to assist teachers in effectively enacting the resource.

DISCUSSION

The teaching and learning of science through inquiry is proposed as an effective methodology for the scientific literacy of students (Aguilera & Perales-Palacios, 2020; Akerson & Bartels, 2023; Romero-Ariza, 2017). Furthermore, it is supported by decades of educational research (Lazonder & Harmsen, 2016; Morales et al., 2018).

However, teachers face various barriers and difficulties in effectively implementing it in the classroom (Baroudi & Helder, 2019; Romero-Ariza et al., 2019). To address these challenges, the present research has presented the design, development, and usability evaluation of IndagApp, an ICT resource for teaching science through inquiry.

In this endeavor, usability testing was crucial to develop an educational resource that is easy to use, efficient, and effective in its purpose (Vlachogianni & Tselios, 2022). The results of the quantitative component of the research show adequate usability of IndagApp, with scores well above the minimum benchmarks recommended in the literature (Bangor et al., 2009; Del Rocio Sevilla-Gonzalez et al., 2020; Lewis, 2018). Three widely used instruments in the literature support that it is a resource that captures user attention, generates interest and enjoyment (reward), is attractive in terms of design and graphics, and is a useful tool for teachers. However, aspects with room for improvement were detected. Thus, the qualitative component of the research allowed the identification of these aspects and provided some suggestions for changes to refine the app. These improvements, such as the inclusion of scaffolding resources or the development of inquiries aligned with the curriculum (LOMLOE, 2020), have been of great value because they have allowed for the improvement of the resource to the needs of the users, namely, science teachers of students aged 10-14 years.

In conclusion, this mixed methods research supports the use of IndagApp as an educational tool for didactic transposition of the inquiry methodology for teaching science in Primary and Secondary Education. It is expected that the development and free availability of this resource will provide teachers with an effective and easy-to-use tool for the adoption of inquiry.

Educational implications

The results of this study have significant educational implications. On one hand, the IndagApp resource can assist Primary and Secondary Education teachers in adopting the inquiry methodology for teaching science (Ali et al., 2022). The use of IndagApp at these stages has the potential to generate learning experiences aligned with curriculum demands and supported by educational research (Oliveira et al., 2019). On the other hand, IndagApp allows for meaningful and enriching use of ICT in the classroom (Silva-Díaz et al., 2022). This aspect enhances students' development of digital competence and promotes problem-solving through the use of digital resources (Marrero-Galván & Hernández-Padrón, 2022). Therefore, its use could lead to an improvement in scientific understanding and interest in science among students, as well as enhancing scientific literacy from the early stages of the educational system (Bozzo et al., 2022; Bravo et al., 2019). However, these aspects require further research with educational interventions grounded in IndagApp.

The analysis of expert responses reveals relevant conclusions for the development of technological resources for teachers that go beyond IndagApp. On the one hand, ICT resources must be agile and visually appealing to maintain user interest and facilitate adoption. Thus, adapting the interface and content to the target audience, considering their age, interests, and needs, is vital for acceptance. In this regard, from a teaching perspective, there is a highlighted need to provide resources with an intuitive and clear user experience, along with detailed explanations of their implementation and use. In the case of IndagApp, the provision of support resources such as video tutorials or explanations within the application has been chosen to increase the teacher's confidence in using the resource.

On the other hand, it is crucial to meet the demand for multi-platform resources (PCs, tablets, etc.) to increase adoption by teachers. Not all educational institutions have the necessary resources for ICT adoption, such as digital tablets. Therefore, IndagApp has been optimized to be used on different devices. Additionally, it is concluded that to promote the acceptance of ICT resources by teachers, a diversification and approach to relevant content adapted and grounded in the current curriculum and learning objectives of the stage must be offered. Therefore, IndagApp addresses ten central scientific contents in the scientific education of Primary and Secondary Education. Finally, to avoid significant disruption in teaching practice, the implementation of ICT resources must align with regular practices. In the case of IndagApp, a student workbook has been developed as a complement to the app, thus integrating material familiar to the teacher into their daily practice.

Avenues for future research

The present study opens new avenues for future research. One fundamental aspect is the analysis of the prolonged use of the IndagApp resource by teachers—both novice and experienced in the use of ICT resources—in the formal context of Primary and Secondary Education classrooms. This analysis would allow identifying difficulties not related to the design of the resource itself, but rather to the didactic strategies that enable its effective implementation. That is, the technological pedagogical content knowledge (TPACK), an aspect that has been identified as a matter of concern (Valtonen et al., 2023). Another aspect to be addressed in future studies is the usability of the app for Primary and Secondary students. In the present study, a panel of experts was employed according to the recommendations of the literature, both in sample size and composition, and expertise. Thus, the usability of the resource was approached from the perspective of teachers, considering effectiveness, efficiency, and satisfaction, which has allowed for improvements in the interface and content of IndagApp.

Following the improvements made and the confirmation of the resource's usability for teachers, the next steps of the project will focus on analyzing the usability by Primary and Secondary students. Informal tests have been conducted with students, yielding satisfactory results, but not related to its use in the formal classroom context or with the necessary rigor. Therefore, future studies with rigorous methodologies and instruments with adequate psychometric properties for the collection of valid and reliable data are required (Lewis, 2014), in addition to other variables of interest such as learning improvement, attitudes, or scientific motivation (Toma, 2021b).

Limitations

The usability results presented in this manuscript should be interpreted considering that two out of the three quantitative instruments used are not validated in Spanish. Attempts have been made to minimize this limitation by translating them into Spanish following cultural adaptation procedures, thus ensuring conceptual and semantic equivalence with respect to their original version (Cohen et al., 2018). Although the levels of internal reliability obtained have been satisfactory for all analyzed dimensions, the results of this research should be interpreted considering this limitation.

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Distance Education, transforming realities: a look at insecure environments

Educación a Distancia, transformar realidades: una mirada en ambientes inseguros

Luis Moncada Mora - *Universidad Técnica Particular de Loja, UTPL (Ecuador)*
Ximena Songor Jaramillo - *Universidad Técnica Particular de Loja, UTPL (Ecuador)*
Gabriela Cornejo Montaño - *Universidad Técnica Particular de Loja, UTPL (Ecuador)*

ABSTRACT

Latin America faces persistent challenges related to high crime rates, creating an environment marked by violence and insecurity. Ecuador has experienced a significant increase in violence in recent years, making it one of the most dangerous countries in the region. This study addresses how insecurity and crime influence enrollment rates in higher education at the undergraduate level, specifically at the Universidad Técnica Particular de Loja (UTPL), by examining how distance education (DE) becomes a safer and more attractive option in areas affected by high rates of insecurity. We use data on the number of students in the DE system provided by the Vice Rectorate of Distance Modality of the UTPL, in addition to homicide data by province between 2019 and 2022 obtained from the Ministry of the Interior of Ecuador. Also, the Gross Value Added (GVA) of the Higher Education sector is considered as a control variable. As an econometric strategy, we used multilevel analysis and regressions for panel data, which confirm the hypothesis put forward: the homicide rate has a positive effect on enrollments in the UTPL's DE system at the provincial level. These findings allowed inferring the significant influence of insecurity and violence on students' educational decisions, motivating the choice of safer educational modalities, such as distance learning.

Keywords: distance learning; higher education; quantitative analysis; violence.

RESUMEN

América Latina enfrenta desafíos persistentes relacionados con altas tasas de delitos, creando un entorno marcado por la violencia y la inseguridad. Ecuador ha experimentado un aumento significativo en la violencia en los últimos años, convirtiéndose en uno de los países más peligrosos de la región. Este estudio aborda cómo la inseguridad y la criminalidad influyen en la tasa de matriculación en estudios superiores a nivel de grado, específicamente en la Universidad Técnica Particular de Loja (UTPL), examinando la forma en la que la Educación a Distancia (EaD) se convierte en una opción más segura y atractiva en zonas afectadas por altos índices de inseguridad. Se utilizan datos del número de estudiantes en el sistema de EaD proporcionados por el Vicerrectorado de Modalidad a Distancia de la UTPL, además de datos de homicidios por provincia entre 2019 y 2022 obtenidos del Ministerio del Interior de Ecuador. También, se considera el Valor Agregado Bruto (VAB) del sector de Enseñanza Superior, como variable de control. Como estrategia econométrica se utilizó principalmente el análisis multinivel y regresiones para datos de panel, las cuales confirman la hipótesis planteada: la tasa de homicidios tiene un efecto positivo en las matriculaciones en el sistema de EaD de la UTPL a nivel provincial. Estos hallazgos permitieron inferir la influencia significativa de la inseguridad y la violencia en las decisiones educativas de los estudiantes, motivando la elección de modalidades educativas más seguras, como es la de estudios a distancia.

Palabras clave: enseñanza a distancia; enseñanza superior; análisis cuantitativo; violencia.

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INTRODUCTION

Latin America is a region facing persistent challenges related to insecurity and crime. High rates of crime such as robbery, assault and drug trafficking have contributed to an environment marked by violence and insecurity compared to other parts of the world (Niño, 2020). The consequences of this violence and conflict for development are profound and affect millions of people in the region (Dammert, 2010; World Bank, 2011).

This issue is reflected in a South American crime index of 5.51/10, which includes a high score of 5.19/10 in the criminal market and a strong influence of criminal structures on security institutions or state control, with a score of 6.63/10 (Observatorio Ecuatoriano de Crimen Organizado, 2022). Accordingly, this index suggests a connection between corruption and the dynamics of organized crime in the region. Moreover, it is highlighted that South and Central America are among the top five regions in the world with the highest crime rates (Observatorio Ecuatoriano de Crimen Organizado, 2022).

The prevailing economic inequality in the region exacerbates insecurity. This inequality often results in the concentration of poverty in urban areas, where the lack of opportunities can become a breeding ground for crime (Vuanello, 2009). Furthermore, several Latin American countries have faced security problems related to drug trafficking and gangs, which have raised significant concerns and eroded the quality of life in affected communities (Cieza, 2009). Corruption and ineffective law enforcement in some countries have also undermined trust in the institutions responsible for maintaining public safety. In this context, insecurity, violence, and crime have left a deep mark on the region, with consequences that transcend various aspects of daily life, including education (Furlán, 2012).

Ecuadorian context

In the specific case of Ecuador, a particularly critical phenomenon has been observed in recent years, as the country has experienced increased growth of criminal markets in the region, within the global crime ranking it retains a rate of 7.07, moving from 35th place in 2021, to 11th in 2023 (Global Organized Crime Index, 2023). According to data provided by the National Police of Ecuador, between January and June 2023, more than 3513 murders were registered throughout the territory (Mella, 2023a). Furthermore, in 2022 the country's homicide rate reached almost twenty-six people per one hundred thousand inhabitants, according to the data portal Statista (Chevalier, 2023). These figures are alarming and show a drastic change in security in a brief period, given that Ecuador went from being one of the safest countries in the region to experiencing a significant increase in its homicide rate, multiplying it by five in just seven years. Under these unfavorable circumstances, it was forecasted that Ecuador would close the year 2023 with a homicide rate of forty per 100,000 inhabitants, positioning itself as the most violent country in the region (Mella, 2023a).

These data reveal that Ecuador is going through one of the worst insecurity crises in its recent history. During the first semester of 2023, there was a 74% increase in the number of violent deaths in the country (Coba, 2023). This increase in violence, driven mainly by the activity of organized crime linked to drug cartels, has placed Ecuador in an alarming position within the Latin American context. The country exhibits some of the highest homicide rates in the region, representing a significant challenge for public safety and the quality of life of its citizens. Paulina Recalde reports that, in 2022, 22% of the population considered insecurity as the country's main problem and by 2023 this percentage increased to 60% (López, 2023).

Poverty, insecurity, and violence in Ecuador not only affect the daily lives of its citizens, but also have a substantial impact on education at all levels (NU, 2023). Students facing these circumstances encounter considerable obstacles to continue their studies in an environment marked by fear and uncertainty (Becker, 2012). This insecurity is not only manifested in the increase in crime, but also undermines society's trust in institutions and public policies responsible for ensuring their safety.

Currently, insecurity has become one of the most significant challenges facing the educational system in Ecuador, impacting young people from various demographic groups, including age, gender, and social strata. The repercussions extend beyond the educational realm into social and economic spheres that affect society (Toscano, 2023). Due to a lack of economic resources in the Highlands and Amazon regions, approximately 40,000 students did not return to the classrooms for the new school year of 2023. In the Costa region, beyond poverty, the shift to virtual classes has become a priority due to the ongoing violence and insecurity that have disrupted regular schooling (La Hora, 2023).

The surge of violence unleashed in Ecuador has led the government to take drastic measures, for example, in Durán, a city on the Ecuadorian coast, more than 30 thousand students from 34 schools were deprived of in-person classes; this decision was taken by the Ministry of Education after an uncontrollable crime wave that has hit this part of the country (Ministerio de Educación del Ecuador, 2023). As of September 2023, 5,320 violent crimes have been reported, of which 1,900 took place in the cities of Guayaquil and Durán (Mella, 2023b). The police have identified that, in the most dangerous area of Guayaquil, specifically in the Nueva Prosperina sector, 16% of students maintain links with criminal groups, according to Roberto Santamaría, head of the Nueva Prosperina District, this situation affects more than two hundred students per educational institution in the sector (Mella, 2023b). Thus, the profound impact that insecurity and violence have on education is evident, causing a notable change in learning dynamics and an exodus of students towards safer educational modalities, such as Distance Education.

Factors impacting continuation of university studies

It is essential to highlight how enrollment in higher education is influenced by a variety of social, economic, and personal factors. These factors go beyond conventional ones such as monetary income, national entrance exams or geographic coverage, as they also include personal conditions and the reality that students face in their environment. Díaz (2008) details the relevant studies that have emerged on this subject, as well as the variables that can guide the analysis of this indicator, covering individual, academic, institutional, and socioeconomic aspects.

In relation to this, there are various analytical models regarding the continuity of students' studies. For example, Bean (1980), based on Tinto (1975), argues that the following factors influence dropout: academic (educational background, academic integration, and performance), psychosocial (goals, perceived usefulness, interaction with peers and teachers), environmental (financing, transfer opportunities, external social relations) and socialization (academic performance, adaptation, and institutional commitment). In addition to these factors, numerous studies have investigated other relevant variables such as adaptation to the educational environment (Spady, 1970), family background and academic performance (Fishbein & Ajzen, 1975; Ethington, 1990), students' socioeconomic level and their academic and social integration (Pascarella & Terenzini, 1980), among other aspects that contribute to understand the complexity of college enrollment (Tinto, 1987; John et al., 2000; Bernal et al., 2000; Tabbodi et al., 2015; Zapata & Perneth, 2016).

On the other hand, within the factors that may affect the retention of students in higher education, the cyclical behavior of the Ecuadorian economy and its relationship with university enrollment should be considered. As Roblez (2019) points out and, supported by previous studies, the countercyclical relationship between enrollment and macroeconomic indicators is not generalizable to countries outside the OECD, as is the case of Ecuador. Here, the relationship between the economy and enrollment tends to be cyclical, influenced by the structure of the labor market and the quality of educational institutions. This economic dynamic may partly explain the preference for distance education during times of crisis, meaning there is an increase in enrollments during both periods of economic expansion and contraction (Seaman et al., 2018).

Role of insecurity in education

Within this context, it is valid to mention that insecurity is defined as the feeling of vulnerability and fear, it has multiple connotations such as the absence of protection, uncertainty, and exposure to risk (Achumba et al., 2013; Hassan, 2014; Adams et al., 2021; Ologele & Fatimah, 2023). This issue knows no borders and affects countries such as the United States and the United Kingdom, constantly challenging the idea of a "perfect peace" in terms of national security (Cooley, 2011). Mori et al., (2004) point out how insecurity undermines the provision of health services, directly impacting on people's wellbeing.

Safety is a crucial pillar for physical, mental, and social well-being; without it, society is immersed in a state of constant fear and danger (Meddings, 2001; Coupland, 2007). This notion of security is not only vital for human health, but also for social stability and the continued development of society (Olamosu, 2000).

In the educational sphere, safety in turn plays a fundamental role. Hirschi (2002) emphasizes the importance of education as an element of social control, providing structure and supervision that discourage participation in criminal activities. Likewise, Gottfredson & Hirschi (1990) suggest that self-control and commitment to school are determining factors in preventing criminal behavior and reducing the levels of insecurity that threaten the stability of a region or locality.

In contexts of increasing insecurity, the lack of a safe school environment may expose students to a greater risk of becoming involved in criminal activities. According to the theory of social bonding, presented by Hirschi (2002), criminal behavior arises when the connection between an individual and society is weakened or broken (Cueto, 2022). It is essential to recognize how educational security influences students' perception of their environment and how this perception affects their participation in criminal activities in communities that evidence high rates of insecurity.

In the face of these challenges, significant changes have been observed in education, especially in areas that are heavily impacted by important levels of insecurity. In Nigeria, for example, educational institutions have migrated from face-to-face instruction to online instruction to counter the effects of insecurity (Akhigbe & Ogunlade, 2022). Online learning has emerged as a solution to overcome geographical and time barriers, allowing access to Distance Education in a flexible and convenient manner (Carmo & Franco, 2019; Akhigbe & Ogunlade, 2022).

In this context, the school not only becomes a learning space, but also a crucial environment for the development of skills and values that promote democratic citizenship in the 21st century (Barrientos et al., 2023). Security, both physical and in access to education, becomes essential to guarantee the continuity of this educational process.

METHODOLOGY

Given the current context of insecurity and the growing incidence of crime in various regions of Ecuador, this research aims to test the hypothesis on the positive effect that the homicide rate has on enrollments in the UTPL's Distance Education system, at the provincial level. In this way, this study modality could be conceived as an attractive and safe alternative for students in areas affected by elevated levels of insecurity. In this sense, this research aims to generate evidence in favor of this modality of higher-level studies as a safer and more convenient option, especially in environments with high insecurity.

UTPL (2023a) stands out as a pioneering institution in the Ecuadorian educational system, especially for its distinctive model of Distance Education DE, with presence in all provinces through a network of support centers. In this research, we consider data on the number of students enrolled in the UTPL's system of distance higher education studies, from April-August 2019 to October 2022-February 2023, comprising a total of eight academic periods. These data were provided by the UTPL's Vice Rector's Office for Distance Learning (UTPL, 2023b). This input of information was consolidated at the regional and provincial level to complement the definitive database of the study.

This research is developed from a longitudinal data set, where the provinces of Ecuador represent the cross-sectional units observed between 2019 and 2022. In addition to academic data taken from the Vice Rectorate of Distance Modality of the UTPL, data associated with violence were taken from the Ministry of the Interior (2022). To ensure the accuracy and validity of the study, key economic data such as the Gross Value Added of the Higher Education Services Sector have been integrated, which were taken from the satellite accounts of Education (INEC, 2022) and, in the analysis is contemplated as a control variable. The information panel has a total of 92 data ($n=92$, $n=x \times t$, where $x=23$ provinces observed during $t=4$ years). The data set is a balanced panel that covers twenty-three continental provinces - the Galapagos Island region is excluded from the analysis, given its characteristics that differentiate it from the other continental provinces of Ecuador - and offers a reliable and complete representation of the information relevant to the study.

Considering the research objectives and the type and structure of the data, three methods were used in the present study to demonstrate the response of the enrollment rate to variations in the violence rate: the first method was Ordinary Least Squares OLS, the second method was the generation of a model under the multilevel methodology and, finally, a panel model was used. The order of application of the methodologies has the sense of gradually unveiling the evidence of the behavior of the relationship proposed in the study, while also seeks rigor through appropriate robust techniques that generate reliable quantitative results.

Likewise, let us consider that social phenomena have characteristics that are associated with the hierarchical nature of the data. This fact means that the position of the observations is determined by their own characteristics as well as by those of the group to which they belong (Cebolla, 2013). The relationship between enrollment and violent events represented by homicides clearly presents a hierarchical component of region and province.

The difference in the intercept and slope could be evidenced in OLS model. This following the graphic evidence and initial exploration of the data, the functional form of this type of behavior is presented in equation 1:

$$Log\ \widehat{enrollment}_i = \alpha_1 + \alpha_2 Region\ + \alpha_3 Homicides + \alpha_4 Region_i * Homicides + \mu_i \tag{1}$$

The multilevel methodology used explored the fixed and random behavior of the data, as well as the hierarchical order of the information. The starting multilevel model is the "empty" one that simply collects the movements of the country mean (fixed part) and the standard error (random part) of the data; its importance lies in the fact that from it the sensitivity or information provided by each nesting level and each explanatory variable will be measured. After several trials, it was determined that the form that most contributed to the explanation of enrollment movements was the mixed-effects multilevel model, whose representation is in equation 2:

$$Log\ \mathrm{enrollment}_{ij} = \alpha_1 + \alpha_2 Region_{0j} + \alpha_3 Homicides_{1j} + \alpha_4 Prov._{ij} + \varepsilon_{ij} \tag{2}$$

Finally, the panel data model – considered to corroborate the results of the multilevel model- is presented in equation 3. Given the evidence of individual effects, the results of the Hausman test reveal the validity of the assumption of the fixed effects model, where $corr(u_{it}, X_{it}) \neq 0$. The expression of the panel fixed effects model to be estimated is expressed as follows:

$$Log\ enrollment_{it} = \alpha + \alpha_1 LogHomicides_{it} + \alpha_2 LogGVA_{it} + \varepsilon_{it} \tag{3}$$
$$\mathrm{i} = 1, 2, \ldots, 23$$
$$\mathrm{t} = 2019, \ldots, 2022$$

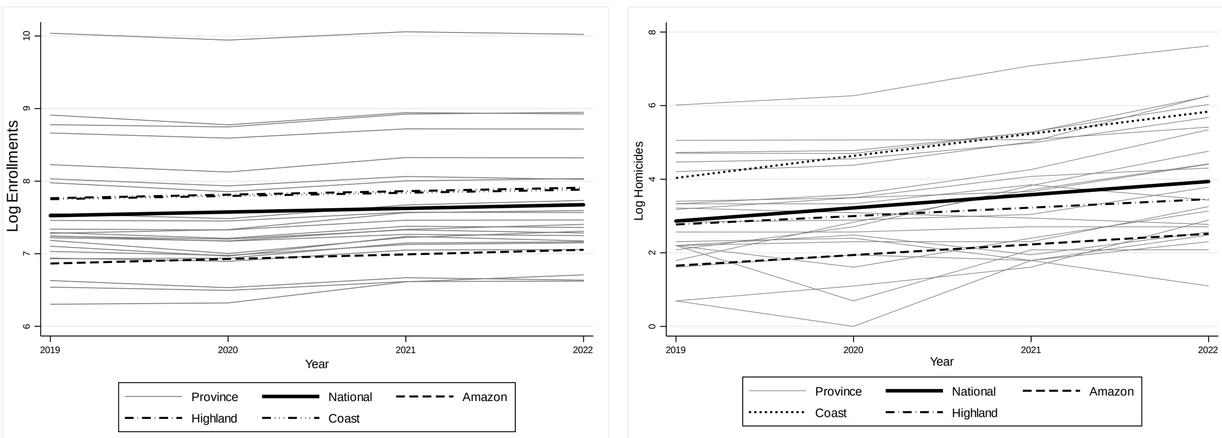
Where, coefficient α_1 represents the slope of the logarithm variable of homicides over the logarithm of enrollment. The coefficient α_2 represents the slope of the GVA of the Higher Education Services Sector, as a control variable. The stochastic disturbance of the panel fixed effects model is represented by ε_{it}. The panel data estimation considers cross-sectional dependence and estimators robust to heteroscedasticity. In the results, two fixed effects estimations are presented: those of the simple model (without including the control for the economic context of the provinces) and the full model (in which the control variable is included), this to verify the stability of the effect identified between the explanatory and the explained variable, in all the econometric modeling carried out.

RESULTS

The comparison shown in Figure 1 highlights the regional and provincial clustering that exists between the enrollment rate and the homicide rate in the four years of study. In addition to a visually evident relationship, there is also a regional clustering consistent with what was presented in the section on the Ecuadorian context. In the provincial case, the results of this behavior will be demonstrated in detail later.

Figure 1

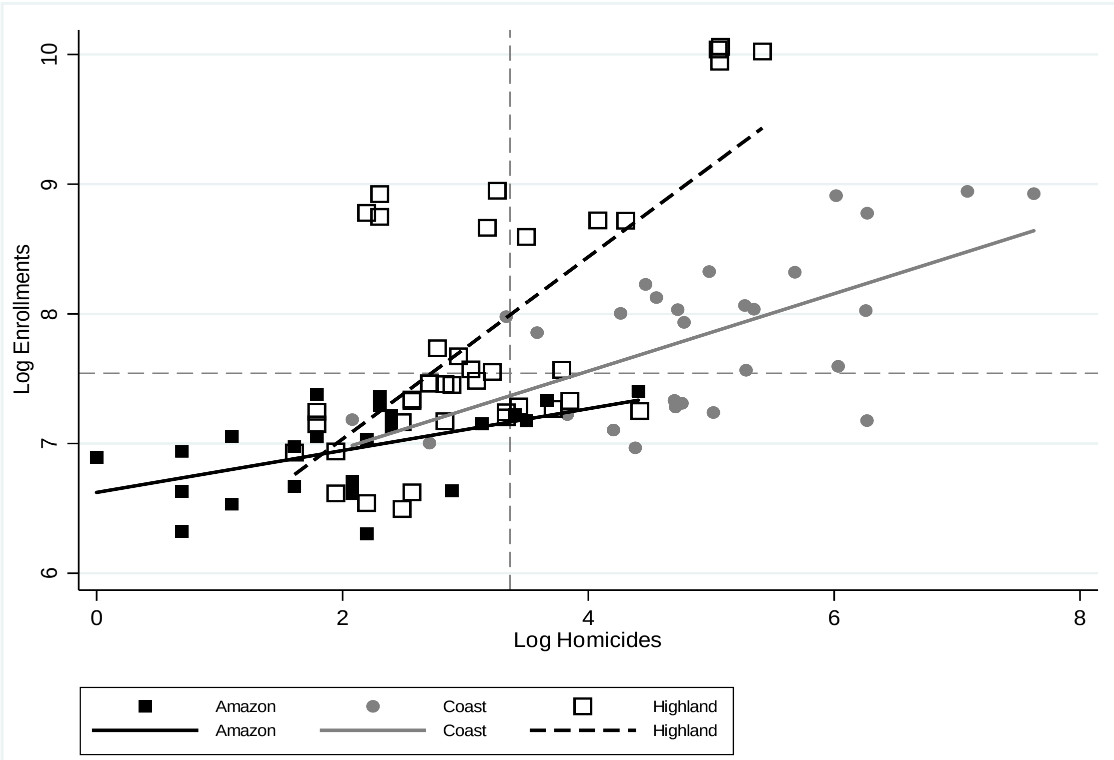
Relationship between enrollment in the distance learning system and violence in the Ecuadorian territory measured through the number of homicides



The average behavior of the enrollment rate was 7.54 with a low dispersion, equal to 0.87 (minimum 5.97 and maximum 10.06), and the average homicide rate was 3.36 with a high dispersion 1.56 (minimum 0 and maximum 7.62). The high dispersion in the homicide rate shows us that there are provinces in all regions that have higher rates of violence, but that, despite this, the enrollment has homogeneous rates throughout the country.

Figure 2

Comparison of the logarithm of enrollment and the logarithm of homicides in Ecuador



The proposed relationship seeks to demonstrate that enrollment in the distance learning system can be affected by violent movements that shake society more, such as homicides. Similarly, a regional and provincial nesting was observed, the latter because people in the territory have heterogeneous ways of life and actions. After this descriptive analysis based on the graphical representation of the variables, the following section presents the results of the corresponding econometric modeling.

Model with intercept and slope difference

Ordinary Least Squares (OLS) estimation, in which an intercept and slope difference was performed for each region, confirmed that the enrollment rate is positively affected by the homicide rate, but that the effects are not the same in each region. The results (equations 4, 5 and 6) for each area are presented below:

$$Log\ Enrollment_{Amazon} = \alpha_{1.1}6{,}12 + \beta_{1.2}0{,}40 + \mu_1 \quad (4)$$
$$Log\ Enrollment_{Coast} = \alpha_{2.1}5{,}84 - \beta_{2.2}0{,}11 + \mu_2 \quad (5)$$
$$Log\ Enrollment_{Highland} = \alpha_{3.1}6{,}56 + \beta_{3.2}0{,}18 + \mu_3 \quad (6)$$

The Coast region has a lower average enrollment rate (5.84) than the other two regions, with a negative slope (-0.11); this result of the most violent region in the country is consistent with the indifference that the population may have to violent events. In contrast, the other two areas have positive movements in the face of violent events such as homicides.

The estimation results are consistent, with goodness-of-fit measures that did not reach the optimum with normalized residuals; this technique was used as a starting point to measure the movements of the proposed relationship. The following subsections of the paper will present the results of techniques appropriate for the data structure and the regional and provincial organization of Ecuador, which are adequate to evaluate the proposed research hypothesis.

Multilevel mixed effects model: multilevel analysis

Based on the preliminary view provided by the OLS model, a hierarchical explanation is proposed using the multilevel methodology, always with the objective of explaining the movements of enrollment in the distance education system based on an indicator of violence with a nesting of region and province.

In the empty model, the fixed part presents a country average enrollment of 7.54 and in the random part of 0.87. Ninety-five percent of the enrollment in the four years of analysis - regardless of region and province - is close to the country average. This initial model was intended to focus the way on which the information is arranged; nevertheless, it was necessary to move forward in terms of the nesting proposed.

In the random intercept model for the continental regions and provinces of Ecuador, the intraclass correlation coefficient was 8 %, which shows that there is no regional nesting; on the other hand, the same coefficient for the arrangement of the data by provinces was 98 %. In this sense, real and significant relationships are guaranteed at the provincial level.

In the mixed effects model, the "logarithm of homicides" was used to reduce the variance between provinces around the country average. Also, the inclusion of the homicide variable seeks to explain the part of the enrollment that is not explained by the country average and by provincial nesting. Likewise, the region was added, not as a nesting level, but as an explanatory variable to determine the direct effects that regional behavior has on enrollment movements. The results are summarized in equation 7:

$$\underset{ee=(0{,}29)\quad(0{,}39)\quad(0{,}36)\quad(0{,}02)\quad(0{,}10)\quad(0{,}01)}{LogEnrollment_{ij} = 6{,}80Amazon + 7{,}46Coast + 7{,}58Highland + 0{,}08Homicides_{ij} + 0{,}70Prov._{ij} + 0{,}09_{ij}} \qquad (7)$$

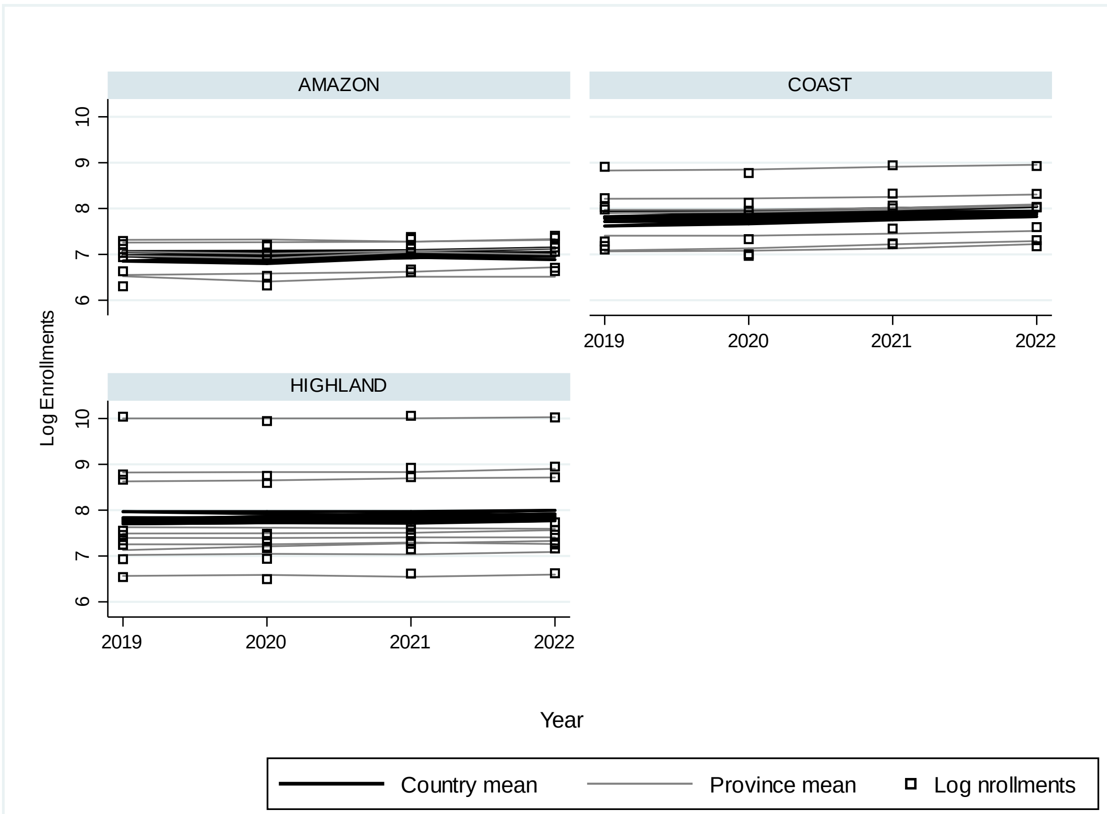
The random parameter for homicides (0.08) shows how enrollment increases when there is more violence in the province. The regions as an independent variable significantly explain the enrollment movements; the Amazon has a mean of 6.80, the Coast has a mean of 7.46 and the Highlands has a mean of 7.58. In all cases the standard errors and the values of the typed variable z (it is normally distributed) allow us to approve the hypothesis that the variables provide information to explain the enrollment movements.

The unexplained dispersion attributed to the provincial level is now 0.70 -0.18 less than in the empty model-, this decrease confirms that the inclusion of the independent variables homicide and region had the expected effect in explaining enrollment movements in the distance learning system. Finally, the intraclass correlation coefficient was 98 %, an indicator that provides assurance that the results are real and significant.

The fit achieved with the mixed effects model, using the logarithm of homicides and the region as independent variables and nesting at the provincial level, is evident in Figure 3.

Figure 3

Multilevel estimates of enrollment, nested by region and province



Fixed effects panel model

To validate the relationship between the homicide rate and the rate of enrollment in higher education studies in DE demonstrated by the multilevel model, the estimation of the panel data is carried out through the Feasible Generalized Least Squares (FGLS) of Parks (1967) and Panel with Standard Error Correction (PCSE) of Beck and Katz (1995). Thus, Table 1 shows the results for the simple model and the full model. The GVA of the Higher Education Services Sector allows us to control for the result of the effect of homicides on higher education enrollments, considering the heterogeneity that exists in the data panel due to the economic wealth that for each territory represents the production process of the higher education service between provinces.

Table 1
Estimates for panel data. Y=Logarithm of enrollment

Variables	No control variables		Control variables	
	PCSE M1	FGLS M2	PCSE M3	FGLS M4
L_Homicides	0,326+ (0,044)	0,309+ (0,018)	0,131+ (0,045)	0,177+ (0,027)
L_GVA			0,332+ (0,058)	0,272+ (0,035)
Constant	6,491+ (0,144)	6,550+ (0,058)	3,770+ (0,500)	4,182+ (0,290)
N	92	92	92	92
R^2	0,352		0,578	

Note. Standard errors in parentheses. Statistical inference: + p<0.01, ** p<0.05, * p<0.1

According to the results in Table 1, the effect of homicides on higher education enrollment in DE is reduced when controlling for the productive heterogeneity (of the higher education sector) of Ecuador's provinces. The coefficient of the control variable is higher than the coefficient of the explanatory variable (this in models 3 and 4). This result does not go against expectations, since it makes sense that the productive dynamics of the higher education sector represents a key factor in the enrollment rate in higher education. However, as can be seen in the results, the stability of the positive effect of homicides on enrollment in distance education is verified: considering fixed effects at the provincial level, the marginal increase in the homicide rate increases on average 0.15 the enrollment rate in higher education.

In summary, the OLS estimation revealed variations in the impact of violence on enrollment by region. While the coastal region showed a negative trend in response to violent events, other areas showed positive movements, suggesting greater sensitivity in educational decision-making in the face of insecurity.

The multilevel model corroborated the positive relationship between homicides and enrollment, showing a significant provincial nesting. The results show how the increase in homicides directly influences the increase in enrollments in HED, especially in areas with higher rates of violence, which could be associated with the benefits offered by this modality of study. Likewise, the inclusion of the Gross Value Added of the Higher Education Services sector as a control variable in the panel model reinforced the stability of the positive effect of homicides on enrollments. This confirms that the productive dynamics of the higher education sector also influences enrollment decisions, although it does not nullify the relationship with insecurity.

In this way, the significant relationship between the enrollment rate and the homicide rate is corroborated (which does not necessarily derive a causal relationship but does provide information to find certain behaviors at a hierarchical level), which, according to the results of the multilevel model, are nested to the provinces of the continental territory of Ecuador, generating different means at each nesting level and different slopes.

According to the results of the panel model, even considering the productive structure of the higher education sector in the Ecuadorian provinces, the positive relationship identified between violence and the enrollment rate, in the context studied, is confirmed.

DISCUSSION AND CONCLUSIONS

Distance Education is a quality response in insecure environments, which reveals a significant change in educational preferences, reflecting the need for more flexible learning environments, demonstrating how perceived safety can influence educational decisions.

The results obtained show a significant relationship represented by the homicide rate and the increase in enrollment in distance studies at UTPL. Through the corresponding econometric techniques, a direct association between these factors was identified, also showing how the perception of an environment influences the educational decisions of students. The link between enrollment and violence is highlighted, showing a regional and provincial grouping coherent with the contextual dynamics of the Ecuadorian territory. The results highlight that, despite variability in homicide rates among provinces, enrollment rates remain relatively homogeneous at the national level.

In a context where security and stability are becoming increasingly elusive, DE emerges as a vital resource, highlighting flexibility and adaptability as fundamental pillars in educational decision-making. Although college enrollment has traditionally been associated with individual, academic, institutional, socioeconomic, and other factors (Spady, 1970; Fishbein & Ajzen, 1975; Tinto, 1975; Bean, 1980; Pascarella & Terenzini, 1980; Tinto, 1987; Ethington, 1990; Bernal et al, 2000; John et al., 2000; Diaz, 2008; Tabbodi et al., 2015; Zapata & Perneth, 2016), this study reveals how the perception of safety becomes a determinant element, with direct impact on students' preferences. It is also important to mention that the country's economic dynamics play a crucial role, evidencing the tendency to seek educational alternatives during periods of economic uncertainty (Roblez, 2019). In this sense, the adoption of distance education is presented as a strategy not only to guarantee access to education, but also as a response mechanism to the social and economic challenges facing communities.

In contrast to the evidence gathered by various studies, such as those of Achumba et al. (2013), Hassan (2014), Adams et al. (2021), Ologele and Fatimah (2023), which highlight the negative impact of insecurity and violence on educational systems, this research reveals a direct effect of insecurity on enrollment rate, under a distance learning system, similar to the situation in Nigeria in 2022 (Akhigbe & Ogunlade, 2022). Generically, these studies reflect how crime, violence and the feeling of insecurity profoundly affect the quality and accessibility of education in contexts of social crisis.

In Ecuador, the adoption of preventive measures, such as the shift from in-person to virtual, has been a response to the high rates of insecurity and crime (Mella, 2023b; Ministerio de Educación del Ecuador, 2023). This situation has led to a decrease in social ties and a growing distrust of traditional institutions, including physical universities. This loss of trust may motivate people to seek educational alternatives that they consider safer and more convenient, to escape the abrupt social changes caused by conflictive environments (García Aretio, 1999). A tangible example of this option is the Distance Education modality offered by the Universidad Técnica Particular de Loja (UTPL).

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A digital world toolkit: enhancing teachers' metacognitive strategies for student digital literacy development

Herramientas para un mundo digital: mejorando estrategias metacognitivas docentes para desarrollar la alfabetización digital del alumnado

Ana Pereles - *Universidad Internacional de La Rioja, UNIR (Spain)*
Beatriz Ortega-Ruipérez - *Universidad Rey Juan Carlos, URJC (Spain)*
Miguel Lázaro - *Universidad Internacional de La Rioja, UNIR (Spain)*

ABSTRACT

The exploration of the relationship between the use of metacognitive strategies and instructional improvement among teachers, with a particular focus on students' media literacy and information management forms the basis for this research study. The study involved 252 teachers enrolled in the master's programme in educational technology at an online university. To assess teaching styles and the integration of the Internet in the classroom, a quantitative methodology was used through the PISA 2018 questionnaire. The results indicate the reliability of the instrument in measuring digital literacy across the seven dimensions addressed. In addition, the Metadig tool is used to measure the metacognitive component in relation to media literacy. It is observed that its application stimulates the acquisition and development of each dimension analysed. Teachers who use metacognitive strategies and promote media literacy enhance the development of digital competence in the classroom. It therefore seems appropriate to integrate well-structured approaches to self-regulated learning through metacognition into teacher education. Metacognition supports effective organisation of learning, control of information and understanding of context, fostering autonomous learning. These efforts promote digital competences in the use of online resources, and ultimately enrich teaching methods and learning strategies.

Keywords: self-regulated learning; metacognitive strategies; computer literacy; cognitive process; learning strategy; distance study.

RESUMEN

La presente investigación analiza la relación entre el uso de estrategias metacognitivas y la mejora de la instrucción entre los docentes, centrándose especialmente en la alfabetización mediática y la gestión de la información de los estudiantes. Participaron en el estudio 252 profesores matriculados en el programa de máster en tecnología educativa de una universidad en línea. Primero, para evaluar los estilos de enseñanza y la integración de Internet en las aulas, se utiliza una metodología cuantitativa a través del uso del cuestionario PISA 2018. Los resultados indican la fiabilidad del instrumento en la medición de la alfabetización digital a través de las siete dimensiones abordadas (utilizar palabras clave, confiar en información de Internet, interpretar información relevante, comprender consecuencias de compartir datos, utilizar descriptores, detectar información subjetiva, detectar spam). Además, para evaluar el componente metacognitivo en vínculo con la alfabetización mediática, se utiliza la herramienta Metadig. Se observa que su empleo estimula la adquisición y el desarrollo de cada dimensión analizada. Los profesores que utilizan estrategias metacognitivas y promueven la alfabetización mediática mejoran el desarrollo de la competencia digital en el aula. Parece apropiado integrar en la formación del profesorado enfoques bien estructurados del aprendizaje autorregulado a través de la metacognición. La metacognición favorece la organización eficaz del aprendizaje, el control de la información y la comprensión del contexto, fomentando el aprendizaje autónomo. Estos esfuerzos promueven las competencias digitales en el uso de recursos en línea y, en última instancia, enriquecen los métodos de enseñanza y las estrategias de aprendizaje.

Palabras clave: aprendizaje autorregulado; estrategias metacognitivas; alfabetización digital; proceso cognitivo; estrategia de aprendizaje; enseñanza a distancia.

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INTRODUCTION

Developing digital competence is a priority in education today. The ability to effectively use digital technologies and access information is essential for students' academic and professional success in an increasingly digitised world (UNESCO, 2016). To meet this challenge, teachers need to play a key role and use effective pedagogical strategies that promote students' digital literacy, as reported in Decision (EU) 2022/2481 of the European Parliament and of the Council setting out the strategic agenda for the Digital Decade to 2030 (European Union, 2021).

There have been numerous frameworks and strategic initiatives to facilitate the acquisition and integration of technological competences, not only for learners, but also for the professional development of educators. Examples include the European Framework for Digital Competence in Education 'DigCompEdu' (Punie & Redecker, 2017) and the European Parliament's (2016) guidelines on lifelong learning. The Digital Competence Framework for Teachers, developed by the National Institute for Educational Technologies and Teacher Training (INTEF, 2022), builds on the European Commission's Digital Education Action Plan (2021-2027) (European Commission, 2021), providing a comprehensive guide for teachers to improve their digital competence and promote the same in students. Accordingly, the PISA 2018 instrument (OECD, 2017, 2019), recognised for its comprehensiveness, assesses a range of digital skills, from the use of search engines to the detection of biased information. Its high reliability underlines its validity and usefulness. The results of PISA 2018 in Reading Skills reveal that one of the variables with the greatest weight in explaining high or low results is the variable of the use of metacognitive strategies (Vázquez-López & Huerta-Manzanilla, 2021).

In this context, the use of metacognitive strategies emerges as a powerful tool for achieving those learning objectives. Metacognitive strategies, as described by Zimmerman and Moylan (2009), involve higher cognitive processes of monitoring, regulating and reflecting on one's own thinking. Those who exercise metacognitive strategies are self-aware of their cognitive processes, recognise their strengths and weaknesses and are able to effectively monitor and regulate their learning, including planning, monitoring and evaluating their performance (Huff & Nietfeld, 2009; Muijs & Bokhove, 2020).

Moreover, metacognition has been identified as a critical factor in teacher professional development, having a significant impact on teaching effectiveness and student learning outcomes (Stephanou & Mpiontini, 2017). Teachers who use metacognitive strategies reflect on their instructional practices, evaluate their efficacy and adapt to respond to students' needs. These strategies promote awareness and control of cognitive processes during lessons (Bannert et al., 2009), which influences students' acquisition and processing of information.

Additionally, teachers' use of metacognitive strategies positively influences students' motivation and engagement (Efklides, 2011; Zimmerman & Moylan, 2009). Research indicates that teachers who promote metacognitive processes and encourage self-regulation in students contribute to improved motivation and academic performance (Kaczkó & Ostendorf, 2023). These strategies also play a key role in the development of critical thinking skills among students (Kaczkó & Ostendorf, 2023), allowing them to critically evaluate information and construct informed arguments. In an attempt to measure these competences, it is noted how the Metadig instrument (Ortega-Ruipérez & Castellanos, 2021) offers an innovative digital solution to foster

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self-regulation of learning. It clearly identifies the metacognitive strategies of planning, monitoring and self-assessment and empowers participants to manage and improve their own learning process during the master's programme (Ortega-Ruipérez & Castellanos, 2023).

In the current educational environment, understanding the importance of metacognitive strategies for promoting digital competence is essential. Teachers employ these strategies to guide students in acquiring digital skills, analysing information and solving problems (Dignath & Büttner, 2018). While promoting self-regulated learning, metacognitive strategies empower students to effectively manage their learning, set goals, monitor progress and make necessary adjustments (Núñez et al., 2022; Wigfield & Cambria, 2010), thereby improving learning outcomes and competences (Panadero, 2017).

Self-regulation and the development of digital competence are closely connected and enhanced through metacognitive strategies (Coll, et al., 2023; Sonnenberg & Bannert, 2019). Media literacy and information processing are integral components of digital skills. Teachers use metacognitive strategies to train students on critically evaluating media messages, understanding data collection and use, and protecting their privacy online (Zheng et al., 2016). Moreover, these strategies support effective communication, collaboration and digital citizenship among students (Villaplana et al., 2022; Suárez & González, 2021), promoting creativity and critical thinking skills (Zimmerman, 2008).

Educators also play a critical role as facilitators for the development of metacognitive skills, promoting autonomy and self-reflection in students (Dobber et al., 2017; Wall & Hall, 2016). Understanding why teachers need advanced metacognitive expertise is essential, as research has established a connection between metacognition and improved academic outcomes, justifying its integration into initial teacher education (Duffy et al., 2009; Perry et al., 2019). Although experienced teachers may sometimes find it difficult to recognise the benefits of metacognitive strategies, such as sharing teaching experiences, the integration of these resources is essential to improve the learning process (Dignath & Büttner, 2018; Halamish, 2018).

Moreover, promoting digital literacy is important, as it involves empowering students with self-regulation skills for information seeking, evaluation and online safety (De Bruyckere et al., 2016). Teachers, again, have an important place as they need effective pedagogical strategies to teach students how to use the Internet appropriately (De Bruyckere et al., 2016).

In view of the changing social and educational scenario, it is essential to prepare teachers in terms of information literacy (Pérez-Escoda, 2017; Monereo, 2011). This includes improving their ability to search for and evaluate information on the Internet, while fostering critical thinking and awareness of online risks (García-Llorente et al., 2020; McDougall et al., 2019). The integration of metacognitive strategies in teacher education is supported as it contributes to the development of information literacy within a more comprehensive digital literacy framework (Arjaya et al., 2013; Salcedo et al., 2022). Even with the acknowledged importance of metacognitive strategies and media and information literacy, there is limited research exploring their interrelationship. It is essential to understand whether teachers skilled in the use of metacognitive strategies can guide students in critically evaluating online information and encourage self-reflection on Internet use.

MATERIALS AND METHOD

The present study has a dual intention. The main purpose of the research is to provide evidence about the reliability of the instrument, to determine whether the selected PISA items are effective in adequately assessing the implementation of good pedagogical practices related to the use of the Internet, with the aim of promoting information literacy.

Secondly, the aim is to check if the employment of a digital tool to facilitate the use of metacognitive strategies for the self-regulation of learning in online teacher training (Metadig), improves the ability to teach media and information literacy. This capacity is part of area 6: Developing students' digital competence, of the Digital Competence in Teaching framework, proposed by the National Institute of Educational Technologies and Teacher Training (INTEF, 2022). To carry out this research, a quasi-experimental design was chosen due to the possibility given to the participants to decide voluntarily whether they wanted to use the tool in question or not. Given these circumstances, it was impracticable to randomly assign them to the research groups.

In order to control the independent variable, an experimental group and a control group were established. In this way, a comparison of the improvements obtained in both groups was made to determine the presence of significant differences and validate whether these improvements can be attributed to the use of the tool under study.

In addition, to ensure a more rigorous control over the independent variable, a pre-post design was implemented, in which data were collected on the dependent variables both before and after the intervention. In this way, we sought to examine the significance of the improvements observed as a consequence of the use of the tool, in comparison with the initial level of application of the metacognitive strategies.

Participants

The study population comprises all students enrolled in the master's program in Educational Technology for Teachers, amounting a total of 650 individuals. The sample selected to carry out the research is composed of 252 students, which represents 38.7 % of the program population. This proportion is considered adequate for making inferences and generalizing the results obtained. The sampling method used in this study is non-probabilistic, as students have the option to participate voluntarily in the research. Consequently, it is a convenience sample.

Regarding the distribution of the participants in the research groups, 42 % of them (105 participants) used the application on a regular basis, while the remaining 58 % (147 participants) only used it during the first few days. These figures have allowed the formation of two study groups: the first one composed of those who used the application on a regular basis (experimental group), and the second one composed of those who did not use it frequently (control group).

Instruments and Materials

In reference to the instruments and materials used, an intervention was carried out through a four-hour training course focused on the use and teaching of self-regulated learning. Participants were offered the voluntary option of using the digital tool Metadig (Ortega-Ruipérez & Castellamos, 2021) in order to self-regulate their own learning process in the master's program. This tool has been designed in a way that clearly distinguishes the three types of metacognitive strategies: planning, monitoring, and self-assessment. Metadig has progressed through iterations based on learner needs, usability and expert validation, proving its effectiveness in improving comprehension, planning and critical thinking (Ortega-Ruipérez & Castellanos, 2023). During the first week, participants were asked to plan their goals and determine the approach they would follow to achieve them. Over the next 15 weeks, corresponding to the duration of the four-month period, the application allowed them to manage and monitor their weekly progress. For the last week, the application included a self-assessment function that allowed them to review which goals were the most difficult to achieve, so that they could spend more time reviewing them.

In this case, the PISA 2018 test (OECD, 2017, 2019) was used; a questionnaire divided into 7 items, each of which is a dimension. It addresses the use of keywords in search engines (item 1), trust in internet information (item 2), as well as the relevance of internet content for schoolwork (item 3). The last four dimensions are the understanding of the consequences of making information public online (item 4), the use of short descriptors below links in search results (item 5), the detection of subjective or biased information (item 6) and, finally, the detection of phishing or spam emails (item 7). The test-retest reliability analysis with our sample yielded a Cronbach's alpha of 0.936.

Procedure and data analysis

Throughout the second term of the master's, an intervention was carried out in which students were contacted a week before the start of the master's course. Through various channels, such as e-mails, notifications in the virtual classroom and telephone calls by tutors, they were informed about the possibility of receiving training to improve their study habits in the master's degree.

The training was divided into two phases. The first part consisted of a two-hour session held during the first week of the term. This lesson explained the concept of self-regulated learning and the importance of using strategies to self-regulate the learning process. Emphasis was put on metacognitive strategies and it was shown how they could apply them if they decided to use the Metadig tool. The use of this tool was presented as optional and framed within the research project. Participants were therefore divided into the experimental group or the control group, depending on whether they chose to use the tool or not. To participate in the study, they were informed about the need to complete a questionnaire that included items from the 2018 PISA test within the Program for International Student Assessment (OECD, 2017), as well as other scales that were part of the research project. Those who could not attend the live session had the option to watch it later for one week. The questionnaire was also available for one week to collect pre-test responses.

Over the following 15 weeks, corresponding to the duration of the four-month period, the students used the tool autonomously, organizing their learning process as they saw fit. They were reminded to use the tool twice during the term, specifically in weeks five and ten. Before the exams, they were also reminded how they could use the self-assessment function of the tool to improve their study.

At the end of the term, the second training session, also lasting two hours, was conducted. This time, the focus was on how participants could teach self-regulation learning strategies to their own students. The first half hour of the session was spent reflecting together on how the tool had helped them and whether they felt that such strategies could be useful for their students. The session ended by thanking them for their participation and again asking them to complete the questionnaire in order to obtain the post-test responses. Similar to the first meeting, those who were not able to attend live had the opportunity to watch it afterwards and answer the questionnaire during the following week.

To address the first objective, an approach called Structural Equation Modelling (SEM) is used. This multivariate analysis technique allows us to test models that propose causal relationships between variables (Ruiz et al., 2010). Unlike regression models, SEM is more flexible and focuses on hypothesis confirmation rather than exploration (Escobedo et al., 2016). SEM is preferable to Confirmatory Factor Analysis (CFA) because it extends the possibility of relationships between latent variables and encompasses both a measurement model and a structural model (Schreiber, 2021). The purpose of SEM is to validate a theory describing the relationships between variables by using empirical data to confirm a theoretical model based on real information.

In this initial stage, various statistics are examined to assess the fit of the models. On the one hand, the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) are used, which are improved compared to the Normalized Fit Index (NFI) and are less sensitive to model complexity. Both indices must be greater than 0.9 to consider that the model has a good fit. On the other hand, the ratio of the chi-square to the degrees of freedom (X^2/df) is used as an index, which must be less than 0.5. Two indices are also used to analyse the residuals: the Root Mean Square Error of Approximation (RMSEA), which indicates how well the model fits the reference population, with lower values indicating a better fit, and is considered acceptable if the value is between 0.05 and 0.08. In addition, the Standardized version of the Root Mean Square Residual (SRMR) summarizes the differences between the observed and estimated variance-covariance matrices, and if the mean standardized residuals exceed 0.1, this indicates a fit problem. Once the model that best fits the data is selected, information on item loadings on the factors is incorporated and reliability is assessed using different statistics. All these data are interpreted together.

In addition, the reliability of the test was verified using the study sample by analysing Cronbach's alpha coefficient for all the items as well as for the items of each dimension. In this way, it was possible to confirm that the measuring instrument used was suitable for assessing media literacy in the context of this sample (α=0.936).

In the second place, two variables were created for each dimension, one based on the pretest items and the other based on the posttest items, calculating the value of the items corresponding to each dimension of study. Finally, it was examined whether the distribution of the sample corresponded to a normal distribution for each dimension. In cases where the dimension followed a normal distribution, a Generalized Linear Model with Gaussian distribution was applied. In cases where the distribution was not normal, a Generalized Linear Model was also used, but the distribution was adjusted to a Gamma distribution for those variables that did not have symmetry. In both cases, the impact of belonging to one group or the other was analysed, i.e., whether the participants had used the Metadig tool to employ metacognitive self-regulation strategies, considering this variable as a factor in the test.

This impact was measured, depending on the group, in each dimension of the study, taking the post-test variable of each dimension as the dependent variable, with the aim of assessing its impact after the intervention. To assess the real impact, free of the pretest effect, the pretest variable of the dimension was included as a covariate.

RESULTS

Objective 1. Quality of the instrument

Initially, it was necessary to examine the model fit indices (Table 1) in order to identify which showed the most optimistic results. While analysing the model, it was observed that the chi-square ratio (divided by the degrees of freedom ($\chi2/df$), the CFI, TLI, SRMR and RMSEA), provided satisfactory results that support the adequate adjustment of the model. In particular, the results obtained for the CFI, TLI and SRMR are notably excellent.

Table 1

Adjustment of measurements of the two models

	X^2/df	CFI	TLI	SRMR	RMSEA
1Factor Model	5.521	0.993	0.989	0.026	0.134

Consequently, the results indicate an adequate adjustment of the model. In this sense, it can be affirmed that the instrument created using the PISA items is able to measure pedagogical practices related to the development of information literacy competence.

Likewise, a very satisfactory fit of the items in each dimension is observed, according to the statistics presented in Table 2. The coefficient of determination (R^2) provides information on the percentage of variance of the factor that is explained by each item, while the standardized beta coefficient reveals its factorial influence.

Table 2

Weights of the items in each dimension in the two-factor model

		R^2	β	z	p
Teaching Practices	Keywords	0.773	0.879		
	Trust	0.830	0.911	58.8	<0.001
	Relevant info.	0.849	0.921	56.1	<0.001
	Consequences	0.684	0.827	35.3	<0.001
	Descriptors	0.786	0.887	49.5	<0.001
	Subjective info.	0.876	0.936	62.7	<0.001
	Spam	0.838	0.915	65.1	<0.001

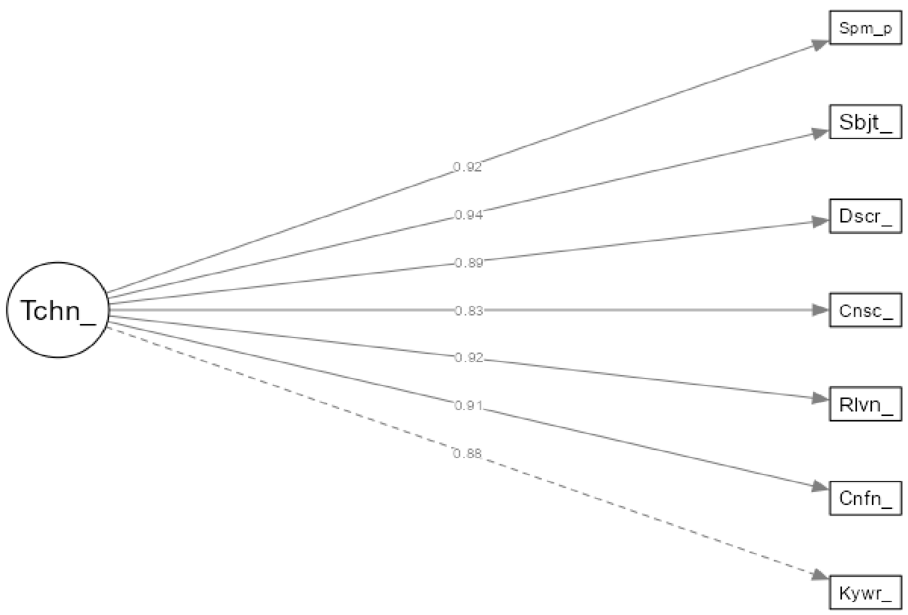
Furthermore, special attention was paid to the reliability indices (Table 3) to ensure the quality of the model, and highly favorable results were obtained. Both the ordinal alpha and the omega 1 exceeded the value of 0.9, which is very positive. In addition, the average variance explained (AVE), representing the mean of the R^2 coefficients of the items in each dimension, reached a value of 0.8. It should be noted that a value of 0.5 is sufficient to consider that the model is adequate, so these results reaffirm the robustness and reliability of the model.

Table 3
Reliability indexes

Variable	α	Ordinal α	ω1	ω2	ω3	AVE
Teaching Practices	0.947	0.965	0.948	0.948	0.955	0.805

Figure 1 shows the beta standardized coefficients representing the factor weights of each item.

Figure 1
Factorial weights (beta) on the factor



Objective 2. Dimensions

In the subsequent section, the differences between dimensions are analysed to understand whether the use of a digital tool to facilitate the use of metacognitive strategies for self-regulation of learning in online teacher training enhances the ability to teach media and information literacy.

How to use keywords when using a search engine

According to the results from the Shapiro-Wilk analysis, it was verified that the data did not follow a normal distribution (p=<.001). Therefore, Generalized Linear Models using the Gamma distribution were applied. First, the model's measure of fit was assessed using the coefficient of determination R^2. In this case, the model suggests that 25.6 % of the variability in terms of teaching improvement in the use of keywords in search engines can be explained using metacognitive strategies through Metadig.

Analysing the results for the estimated parameters of the model (Table 4), the predictors (group and pretest) are statistically significant (p<0.001). When controlling the effect of the pretest, it is found that the mean value of those who did not use Metadig to improve their teaching of media and information literacy is 2.38 points out of 4. On the contrary, those who did use Metadig regularly could obtain 1 additional point in teaching management, thus reaching a score of 3.38 points.

The differences between the groups, after adjusting for the pretest effect, were confirmed as significant by the Bonferroni test (Table 5). These differences can be graphically seen in Figure 2.

Table 4

Parameter Estimates for How to use keywords when using a search engine

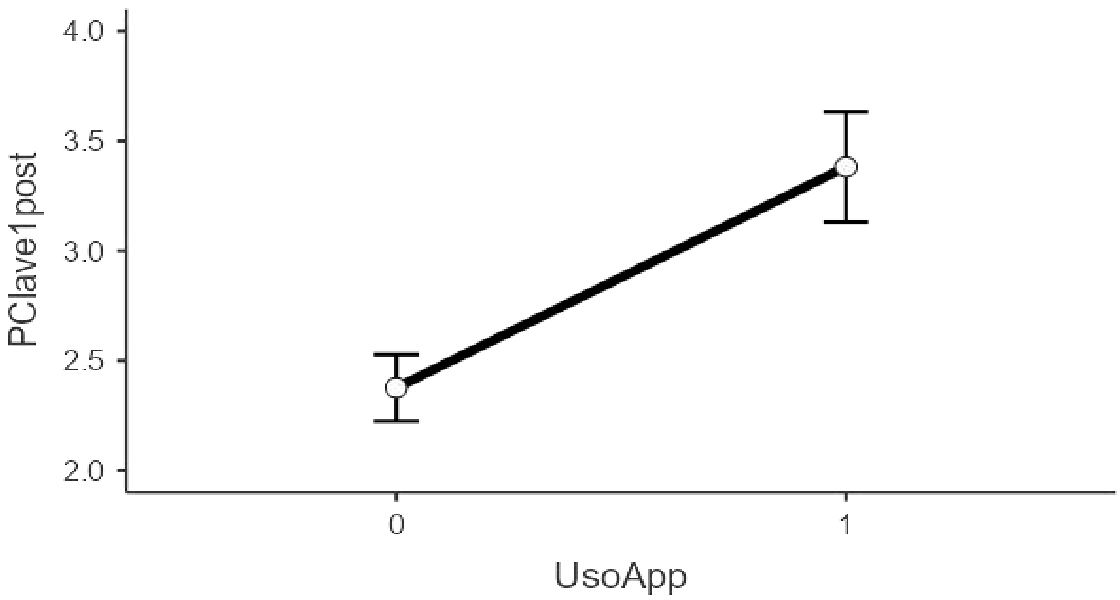
				95 % Confidence Interval			
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	***z***	***p***
(Intercept)	(Intercept)	2.376	0.0772	2.233	2.532	30.76	< .001
UsoApp1	1 - 0	1.005	0.1466	0.726	1.299	6.86	< .001
PClave1	PClave1	0.418	0.0631	0.293	0.547	6.63	< .001

Table 5

Post Hoc Comparisons UsoAPP for How to use keywords when using a search engine

Comparison						
UsoApp		**UsoApp**	**Difference**	**SE**	**z**	**$p_{bonferroni}$**
0	-	1	-1.01	0.147	-6.86	<.001

Figure 2
Plots estimated marginal means by group for How to use keywords when using a search engine



How to decide whether to trust information from the Internet

Once the Shapiro-Wilk test was examined, it was observed that it did not follow a normal distribution (p=< .001), so the Generalized Linear Models test with the Gamma distribution was used. Firstly, the model fit measure with R^2 was observed, which suggests that 28.2 % of the improvement in media literacy in deciding whether to trust information on the Internet could be explained by the regular use of metacognitive strategies through Metadig.

The results suggest that the predictors are also statistically significant (p<0.001). According to the parameter estimates in Table 6, when considering the effect of the pretest on the sample, those individuals who did not use Metadig to apply digital literacy would obtain a mean score of 2.78 out of 4. On the other hand, those who used the tool would achieve 3.61 points, which represents an increase of 0.82 points compared to the group that did not use this tool. The Bonferroni test (Table 7) confirms that this difference between the groups is statistically significant, as shown in Figure 3.

Table 6
Parameter Estimates for How to decide whether to trust information from the Internet

				95 % Confidence Interval			
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	***z***	***p***
(Intercept)	(Intercept)	2.784	0.0659	2.660	2.916	42.23	< .001
UsoApp1	1 - 0	0.822	0.1174	0.595	1.057	7.01	< .001
Confi2	Confi2	0.457	0.0517	0.347	0.563	8.82	< .001

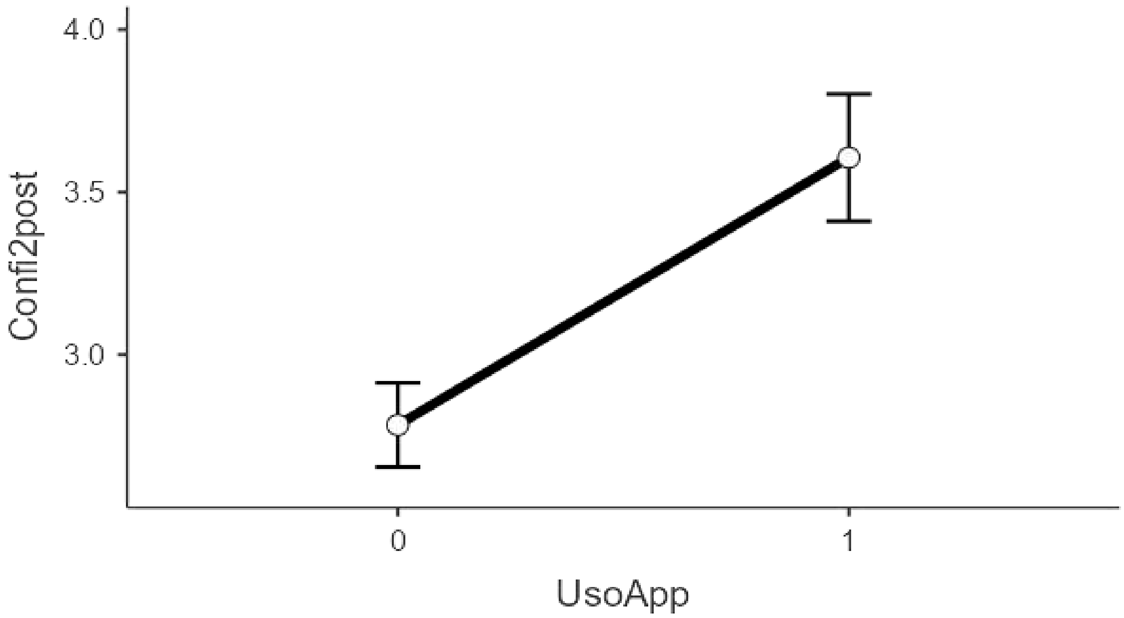
Table 7

Post Hoc Comparisons UsoAPP for How to decide whether to trust information from the Internet

Comparison						
UsoApp		UsoApp	Difference	SE	z	$p_{bonferroni}$
0	-	1	-0.822	0.117	-7.01	< .001

Figure 3

Plots estimated marginal means by group for How to decide whether to trust information from the Internet



How to compare different web pages and decide relevant information

Analysis of the Shapiro-Wilk test showed that the data did not follow a normal distribution (p=<.001). Therefore, the Generalized Linear Models test with a Gamma distribution was applied. Firstly, the measure of model fit was evaluated by means of the R^2 coefficient, indicating a 28 % variability in teacher improvement in media literacy, specifically in the ability to compare different web pages and determine the relevance of information for schoolwork, which could be explained by the regular use of metacognitive strategies through Metadig.

The obtained results reveal that the predictors are also statistically significant (p<0.001). According to the parameter estimates in Table 8, when considering the effect of the pretest on the sample, those individuals who do not use Metadig to apply digital literacy would obtain a mean score of 2.59 out of 4. On the other hand, those using this tool would achieve a score of 3.52 points, which represents an increase of 0.92 points compared to the group not using Metadig. The Bonferroni test (Table 9) confirms that this difference between the groups is statistically significant, as shown in Figure 4.

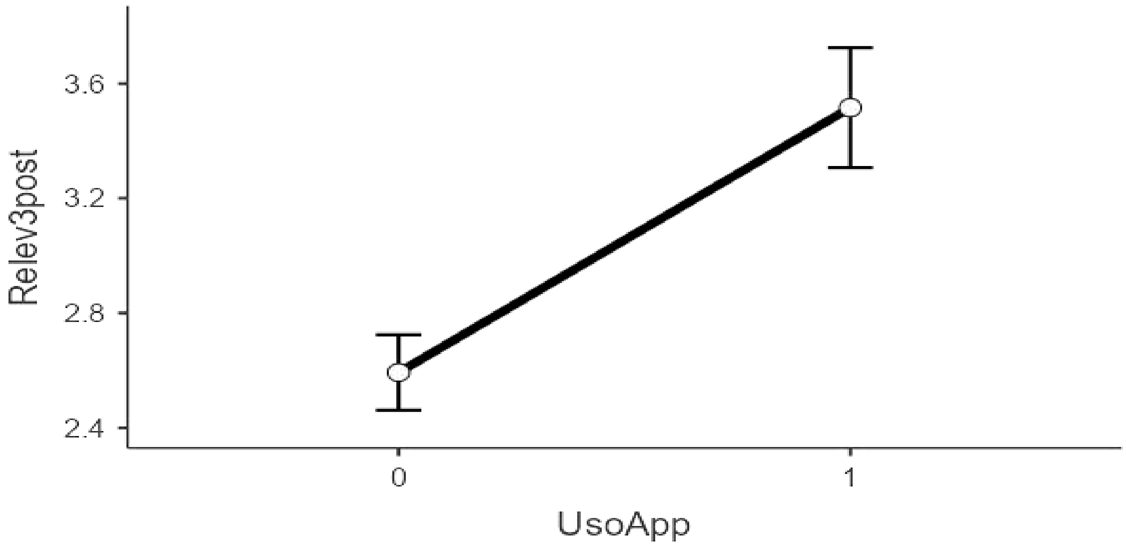
Table 8
Parameter Estimates for How to compare different web pages and decide relevant information

				95 % Confidence Interval			
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	***z***	***p***
(Intercept)	(Intercept)	2.593	0.0673	2.466	2.728	38.55	< .001
UsoApp1	1 - 0	0.923	0.1237	0.683	1.171	7.46	< .001
Relev3	Relev3	0.423	0.0555	0.309	0.536	7.62	< .001

Table 9
Post Hoc Comparisons UsoAPP for How to compare different web pages and decide relevant information

Comparison						
UsoApp		**UsoApp**	**Difference**	**SE**	**z**	**$p_{bonferroni}$**
0	-	1	-0.923	0.124	-7.46	< .001

Figure 4
Plots estimated marginal means by group for How to compare different web pages and decide relevant information



Understanding the consequences of making information publicly available online on social media

While analyzing the data obtained with the Shapiro-Wilk test, it was observed that the data do not follow a normal distribution (p=<.001). Therefore, the Generalized Linear Models test with a Gamma distribution was used. Thus, the measure of model fit was assessed using the R^2 coefficient, which indicates that 27.1 % of the variability in teacher improvement in media literacy related to understanding the consequences of making information public on social networks could be explained by the regular use of metacognitive strategies through the tool.

These results shows that the predictors were also statistically significant (p<0.001). According to the parameters estimated in Table 10, when considering the effect of the pretest on the sample, it is observed that those individuals who did not use Metadig to apply digital literacy would obtain a mean score of 2.78 out of 4. On the other hand, those who used this tool would achieve a score of 3.64 points, which implies an increase of 0.87 points compared to the group that did not use this tool. The Bonferroni test (Table 11) confirms in a statistically significant way that there is a difference between the groups, as can be seen in Figure 5 below.

Table 10

Parameter Estimates to understand the consequences of making information publicly available online on social media

				95 % Confidence Interval			
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	***z***	***p***
(Intercept)	(Intercept)	2.776	0.0694	2.646	2.915	40.01	< .001
UsoApp1	1 - 0	0.867	0.1229	0.627	1.114	7.06	< .001
Consec4	Consec4	0.497	0.0494	0.391	0.601	10.06	< .001

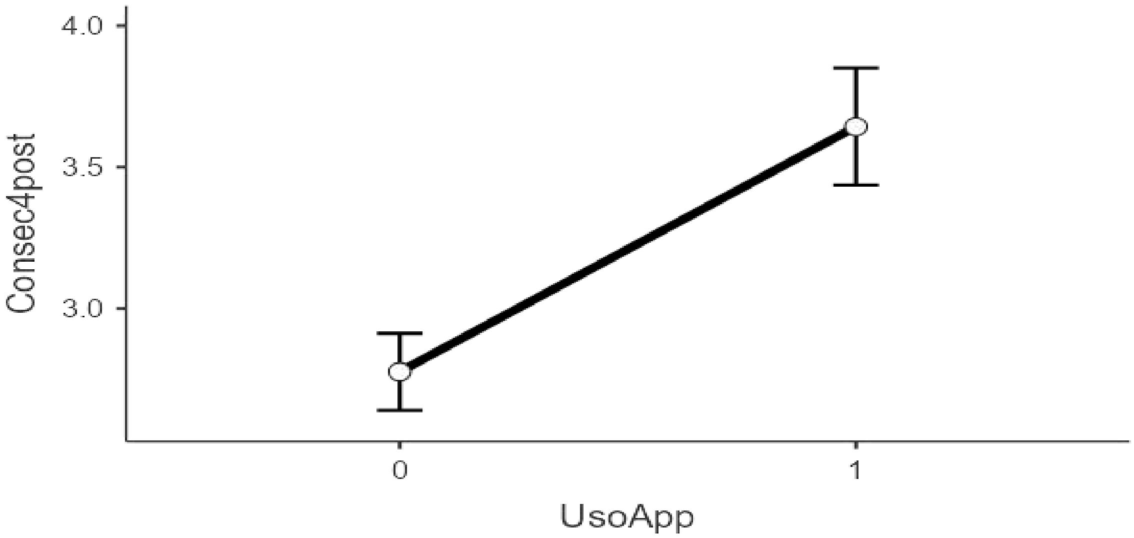
Table 11

Post Hoc Comparisons UsoAPP to understand the consequences of making information publicly available online on social media

Comparison						
UsoApp		**UsoApp**	**Difference**	**SE**	**z**	$\mathbf{p_{bonferroni}}$
0	-	1	-0.867	0.123	-7.06	< .001

Figure 5

Plots estimated marginal means by group to understand the consequences of making information publicly available online on social media



How to use the short description below the links in the list of results of a search

After carrying out the analysis with the Shapiro-Wilk test, it was observed that the data do not follow a normal distribution (p=.002), therefore, it was decided to use the Generalized Linear Models test with a Gamma distribution. Firstly, the fit of the model was evaluated using the R^2 coefficient, suggesting that 23.6 % of the variability in teacher improvement in terms of media literacy, specifically in the ability to use the brief description that appears under the links in the list of search results, could be explained by the regular use of metacognitive strategies through Metadig.

The findings reveal that the predictive variables also demonstrate statistical significance (p<0.001). According to the parameter estimates in Table 12, when considering the effect of the pretest on the sample, those individuals who did not use Metadig to apply digital literacy would obtain a mean score of 2.38 out of 4. In contrast, those who used this tool would achieve a score of 3.31 points, which implies an increase of 0.93 points compared to the group that does not use this tool. The Bonferroni test (Table 13) supports the evidence that this difference between the groups is statistically significant, as shown in Figure 6.

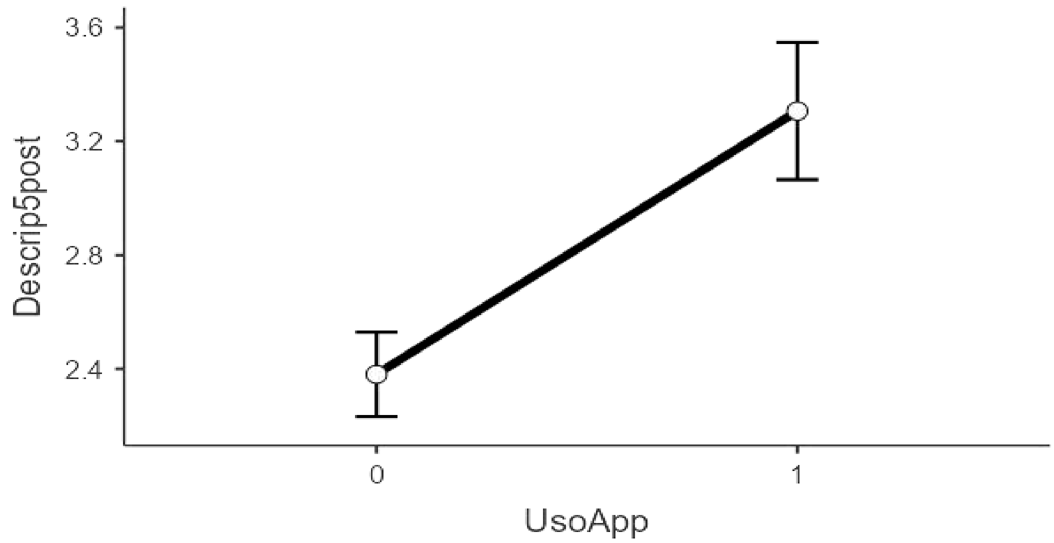
Table 12
Parameter Estimates for How to use the short description below the links in the list of results of a search

Names	Effect	Estimate	SE	95 % Confidence Interval Lower	95 % Confidence Interval Upper	*z*	*p*
(Intercept)	(Intercept)	2.381	0.0757	2.240	2.534	31.44	< .001
UsoApp1	1 - 0	0.926	0.1425	0.654	1.211	6.50	< .001
Descrip5	Descrip5	0.387	0.0680	0.254	0.524	5.69	< .001

Table 13
Post Hoc Comparisons UsoAPP for How to use the short description below the links in the list of results of a search

Comparison UsoApp		Comparison UsoApp	Difference	SE	z	$p_{bonferroni}$
0	-	1	-0.926	0.142	-6.50	< .001

Figure 6
Plots estimated marginal means by group for How to use the short description below the links in the list of results of a search



How to detect whether the information is subjective or biased

The results of the Shapiro-Wilk test were evaluated and it was observed that the data do not follow a normal distribution (p=.002). It was therefore decided to use the Generalized Linear Models test with a Gamma distribution. In the first stage, the ability of the model to fit the data was assessed using the R^2 coefficient. The results show that 25.9 % of the improvement in teacher competence in media literacy, specifically in the ability to identify whether information is subjective or biased, could be explained by the regular application of metacognitive strategies through the tool.

In addition, statistically significant results (p<0.001) were obtained for the predictors. The parameter estimates in Table 14 indicate that, when considering the effect of the pretest on the sample, those individuals who did not use Metadig to promote digital literacy would obtain a mean score of 2.42 out of 4. On the other hand, those who made use of this tool would achieve a score of 3.34 points, which represents an increase of 0.92 points compared to the group that did not use Metadig. The results of the Bonferroni test (Table 15) significantly confirm that there is a statistical difference between the groups, as shown in Figure 7 below.

Table 14

Parameter Estimates for How to detect whether the information is subjective or biased

				95 % Confidence Interval			
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	***z***	***p***
(Intercept)	(Intercept)	2.424	0.0708	2.291	2.568	34.24	< .001
UsoApp1	1 - 0	0.915	0.1327	0.660	1.180	6.89	< .001
Subje6	Subje6	0.352	0.0608	0.235	0.472	5.79	< .001

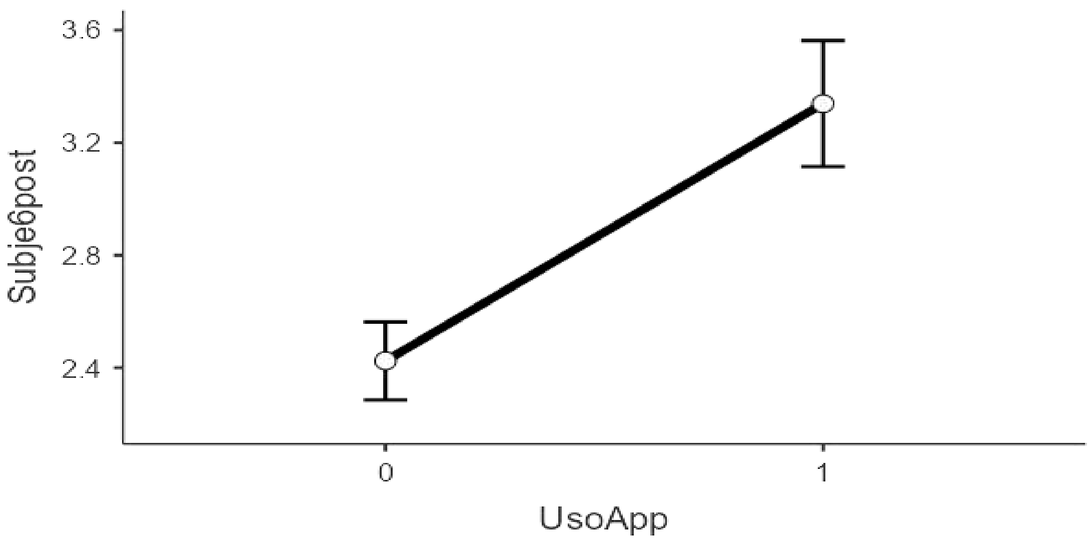
Table 15

Post Hoc Comparisons UsoAPP for How to detect whether the information is subjective or biased

Comparison						
UsoApp		**UsoApp**	**Difference**	**SE**	**z**	$p_{bonferroni}$
0	-	1	-0.915	0.133	-6.89	< .001

Figure 7

Plots estimated marginal means by group for How to detect whether the information is subjective or biased



How to detect phishing or spam emails

From the results obtained in the Shapiro-Wilk test, it was found that the data do not follow a normal distribution (p=<.001). Therefore, Generalized Linear Models analysis with the Gamma distribution was employed. First, the model's measure of fit was assessed using the coefficient of determination R^2. In this case, the model suggests that 22 % of the variability in terms of teaching improvement in detecting phishing or spam emails can be explained using metacognitive strategies through the instrument.

Analysis of the results from the estimated parameters of the model (Table 16) shows that the predictors (group and pretest) are statistically significant (p<0.001). When the effect of the pretest was controlled for, it was found that the mean value of those who did not use Metadig to improve their media and information literacy teaching was 2.50 points out of 4. On the contrary, those who used Metadig regularly could score an additional 0.92 points in teaching management, thus reaching a score of 3.42 points.

The differences between the groups, once adjusted for the pretest effect, were confirmed as significant by the Bonferroni test (Table 17). These differences can be seen graphically in Figure 8.

Table 16

Parameter Estimates for How to detect phishing or spam emails

				95 % Confidence Interval			
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	***z***	***p***
(Intercept)	(Intercept)	2.499	0.0747	2.359	2.650	33.44	< .001
UsoApp1	1 - 0	0.920	0.1386	0.651	1.200	6.64	< .001
Spam7	Spam7	0.369	0.0584	0.257	0.483	6.33	< .001

Table 17

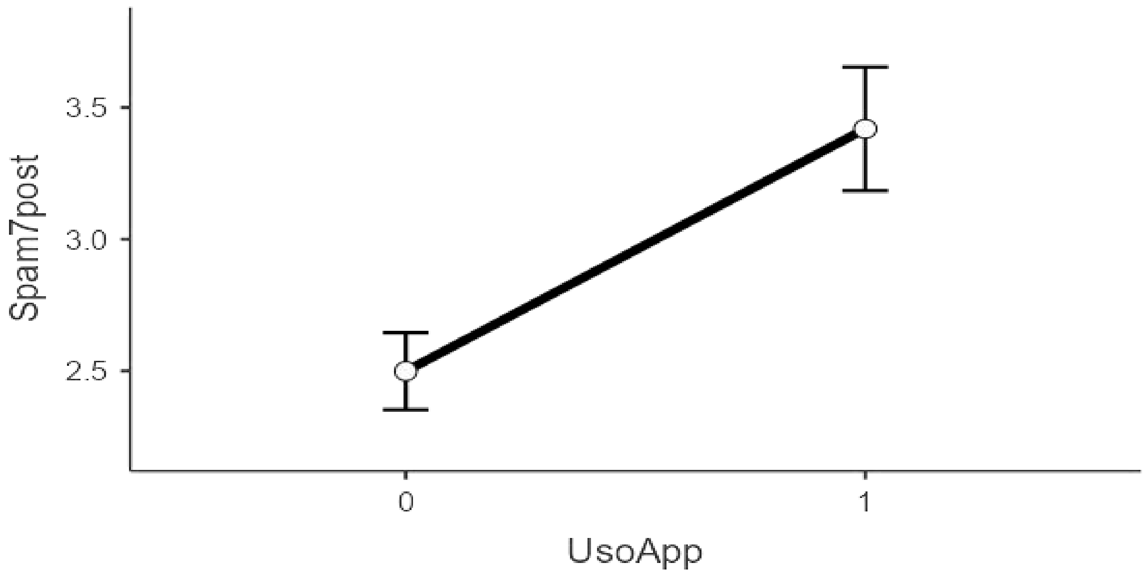
Post Hoc Comparisons UsoAPP for How to detect phishing or spam emails

Comparison						
UsoApp		**UsoApp**	**Difference**	**SE**	**z**	$p_{bonferroni}$
0	-	1	-0.920	0.139	-6.64	< .001

Pereles, A., Ortega-Ruipérez, B., & Lázaro, M. (2024). A digital world toolkit: enhancing teachers' metacognitive strategies for student digital literacy development. [Herramientas para un mundo digital: mejorando estrategias metacognitivas docentes para desarrollar la alfabetización digital del alumnado]. *RIED-Revista Iberoamericana de Educación a Distancia, 27*(2), pp. 267-294. https://doi.org/10.5944/ried.27.2.38798

Figure 8

Plots estimated marginal means by group for How to detect phishing or spam



According to the results in Table 18, a consistent utilization of metacognitive strategies, via the Metadig tool, significantly contributes to enhancing the teaching of various aspects of media literacy. To be precise, it accounts for 28.2 % of the improvement in teaching about the reliability of information hosted on the Internet, followed by 27.4 % in discriminating the relevance of sources and 27.1 % in understanding the consequences of sharing information on social networks. In addition, the use of Metadig explains approximately 25 % of the variability between individuals who use the tool and those who do not. These differences are particularly notable in the dimensions related to the recognition of subjective information (25.9 %), the use of keywords (25.6 %) and the use of search engine descriptors (25.6 %). Furthermore, there is a significant advancement, albeit to a lesser extent, in the dimension of detecting phishing or spam in emails (22 %). It is important to note that significant differences were found between the groups in all cases, controlling for the pretest effect and assuming equality of the groups.

Table 18

Factor results

Dimension	R^2	Mean G-0	Mean G-1	Difference
Keywords	0.256	2.38	3.38	1
Trust	0.282	2.38	3.61	0.822
Relevant info.	0.274	2.59	3.52	0.923
Consequences	0.271	2.78	3.64	0.867
Descriptors	0.236	2.38	3.31	0.926
Subjective info.	0.259	2.42	3.34	0.915
Spam	0.220	2.50	3.42	0.920

Analyzing the mean differences between the groups in each dimension and controlling for the pretest effect, it was observed that the greatest difference was found in the instruction concerning the use of keywords (1 point), followed by the use of descriptors (0.93) and the evaluation of the relevance of the information available on the Internet (0.92). At the same level, we found very high differences in the detection of spam (0.92) and subjective information (0.92). All these variations showed a range equal to or close to one point on the four-point scale used for the measurements. In addition, substantial differences were found in the following dimensions: understanding the implications of sharing information on social networks (0.87) and identifying reliable information (0.82), between those who used and those who did not use Metadig.

CONCLUSIONS

The study has two main objectives: to assess the reliability of the selected PISA 2018 items to measure information literacy teaching practices and to find out whether the use of a digital tool such as Metadig, which develops metacognitive strategies for the self-regulation of learning, improves the teaching of media and information literacy. Therefore, seven dimensions have been analysed according to Pérez-Escoda et al. (2019) for teachers to master in order to address the teaching of media and information literacy (Gutiérrez-Martín et al., 2022).

First, the effectiveness of the PISA 2018 instrument in assessing information literacy pedagogical practices is confirmed, supporting previous research (García-Llorente et al., 2020). Furthermore, it highlights the importance of integrating metacognitive strategies into teacher education, which is considered crucial for improving information literacy (Zimmerman & Moylan, 2009). Validity and reliability analyses of the instrument support its use in measuring information literacy skills (OECD, 2017, 2019).

Furthermore, the impact of the use of Metadig on media and information literacy teaching is analysed. Significant improvement is observed in several key dimensions. Regarding the use of keywords in search engines, teachers develop strategies to conduct more effective searches, promoting students' adaptability and comprehension (Reisoğlu et al., 2020; Zhou, 2023). The tool also strengthens the ability to assess the reliability of online information, which is essential in a context of misinformation (Muijs & Bokhove, 2020). It also facilitates the comparison of information sources and the determination of their relevance, promoting critical thinking and informed decision-making (Bannert et al., 2009; Kaczko & Ostendorf, 2023).

Teachers using Metadig are found to have a better understanding of the consequences of sharing information online, encouraging strategies for responsible use of social networks (De Bruyckere et al., 2016). They improve their ability to use short descriptors in search results, enhancing the analysis and synthesis of information (Dignath & Büttner, 2018). As a result, teachers more accurately detect biased information, fostering the development of pedagogical strategies that promote learner autonomy (Dobber et al., 2017). Finally, they are better able to identify phishing or spam emails, increasing online safety awareness and developing protection strategies (Zheng et al., 2016).

These results highlight the effectiveness of both the PISA 2018 instrument and Metadig in improving the teaching of media and information literacy. After reviewing each one of the dimensions, the study reveals that the use of Metadig, a digital tool that promotes metacognitive strategies, has a positive impact on various dimensions of media and information literacy teaching. This is evidenced by improving the use of keywords in search engines, developing the ability to evaluate online information, improving the determination of the relevance of content for schoolwork, understanding the implications of sharing information online, strengthening information analysis and synthesis skills, promoting critical evaluation of the veracity of information, and raising awareness of online safety and identifying risks such as phishing emails or spam.

DISCUSSION

Finally, the present research provides significant evidence on the influence of pedagogical practices on the development of information literacy competence, supporting previous findings (García-Llorente et al., 2020). Furthermore, it shows that the use of digital tools such as Metadig improves dimensions related to information literacy competence (Azevedo & Witherspoon, 2009).

The integration of information technologies with metacognitive strategies in teacher education is crucial for developing media literacy (Beetham & Sharpe, 2013). This approach benefits students to identify reliable sources and make informed decisions (Kaczkó & Ostendorf, 2023; Villaplana et al., 2022). Therefore, teacher training in the use of metacognitive strategies is recommended to improve their self-regulated learning skills.

Furthermore, the importance of continuous training in media and information literacy for teachers is highlighted (Cabrero-Almenara & Palacios-Rodríguez, 2020). The study provides empirical evidence of the role of digital tools in the development of metacognition in education, thus strengthening disciplinary practice in media and information literacy.

Limitations of the study

There are some limitations to this study. On the one hand, the evaluation was conducted in the short term, which prevents us from fully exploring the long-term impact of Metadig use on digital literacy skills (Area & Pessoa, 2012; Azevedo & Witherspoon, 2009). In addition, variables such as prior experience with technology (Martin & Madigan, 2006) or level of familiarity with metacognitive strategies were not considered, which could influence the results (Bannert et al., 2009).

Limitations include self-selection bias, which makes generalization difficult. Future research should address these issues to better understand the impact of Metadig on metacognition and media literacy.

Future lines of research

Further research on Metadig suggests longitudinal studies to measure its impact over time. It is interesting to compare Metadig with other tools to assess its effectiveness in improving metacognitive strategies and digital literacy.

It could also be relevant to explore the link between innovative pedagogical practices and information literacy using PISA data. In addition, investigating moderating variables such as intrinsic motivation and adaptability may shed light on the effectiveness of the tool. This type of research helps to understand the benefits of interventions in diverse educational and social settings.

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The seductive details in online mathematics learning

Los detalles seductores en el aprendizaje en línea de matemáticas

Jimmy Zambrano Ramírez – *Universidad del Pacífico, UP (Ecuador)*
Esthela Gabriela Centeno Martínez – *Unidad Educativa San Rafael (Ecuador)*
Elvira Janneth Legarda Márquez – *Unidad Educativa Humberto Mata Martínez (Ecuador)*
Amelia Chelita Bravo Loaiza – *Colegio de Bachillerato Marcabelí (Ecuador)*
Marcia Yaguarema Alvarado – *Universidad del Pacífico, UP; Colegio Alemán Humboldt de Samborondón (Ecuador)*

ABSTRACT

The new technologies and multimedia formats have given rise to highly attractive synchronous virtual environments for learning mathematics. However, the cognitive theory of multimedia learning suggests that it is preferable to eliminate seductive information from a multimedia presentation. Nevertheless, it is still unclear whether this effect manifests in ecological situations such as synchronous video conferences. In order to address this gap, two experiments were conducted to examine the effect of instructional, decorative, and seductive images on mathematics learning through synchronous video conferences, for both beginner and advanced students. The first experiment (n = 156) revealed that both materials with instructional graphics and materials without graphics are more efficient (i.e., they generate higher performance with equal mental effort) than materials with seductive graphics. In the second experiment, the moderating role of prior knowledge was analyzed (n = 163), including advanced students in the study. The results suggested that novice students performed better with materials containing instructional and decorative graphics compared to those presenting seductive graphics. However, this disadvantage of learning with seductive graphics disappeared in advanced students. It is concluded that the effectiveness of online mathematics learning depends on the type of graphics used and the level of prior knowledge. These results are discussed from the perspective of cognitive load and multimedia learning, and practical guidelines are provided for teaching and researching online mathematics learning.

Keywords: didactic use of computer; multimedia system; mastery learning; cognitive ability; learning process.

RESUMEN

Las nuevas tecnologías y los formatos multimedia han dado lugar a ambientes virtuales sincrónicos de aprendizaje de matemáticas muy atractivos. No obstante, la teoría cognitiva del aprendizaje multimedia sugiere que es preferible eliminar la información seductora de una presentación multimedia. Sin embargo, aún no está claro si este efecto se manifiesta en situaciones ecológicas como las videoconferencias sincrónicas. Con el fin de abordar esta brecha, se llevaron a cabo dos experimentos para examinar el efecto de las imágenes instructivas, decorativas y seductoras en el aprendizaje de matemáticas mediante videoconferencias sincrónicas, tanto para estudiantes principiantes como avanzados. El primer experimento (n = 156) reveló que tanto los materiales con gráficos instructivos como los materiales sin gráficos son más eficientes (i.e., generan mayor desempeño con igual esfuerzo mental) que los materiales con gráficos seductores. En el segundo experimento, se analizó el papel moderador del conocimiento previo (n = 163), incluyendo estudiantes avanzados en el estudio. Los resultados sugirieron que los estudiantes principiantes obtuvieron un mejor desempeño con materiales que contenían gráficos instructivos y decorativos en comparación con aquellos que presentaban gráficos seductores. Sin embargo, esta desventaja de aprender con gráficos seductores desapareció en los estudiantes avanzados. Se concluye que la efectividad del aprendizaje en línea de matemáticas depende del tipo de gráfico utilizado y del nivel de conocimiento previo. Estos resultados se discuten desde la perspectiva de la carga cognitiva y del aprendizaje multimedia, y se proporcionan orientaciones prácticas para la enseñanza e investigación del aprendizaje en línea de las matemáticas.

Palabras clave: aprendizaje asistido por ordenador; sistema multimedia; aprendizaje del dominio; capacidad cognitiva; proceso de aprendizaje.

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INTRODUCTION

A widespread assumption is that digital technologies contribute to innovation and improvement in education and learning (Haleem et al., 2022; Miralles Martínez et al., 2019). These technologies encompass devices, multimedia materials (e.g., graphics and texts), and communication channels, integrated within the term online learning, to foster the acquisition of knowledge (Clark & Mayer, 2024). To ensure that the enthusiasm for technologies leads to greater learning gains, the design and use of digital environments should consider the characteristics of the human cognitive architecture (Sweller, 2024). The most relevant aspects of this architecture are working memory, long-term memory, and the processes that occur between them (Forsberg et al., 2021).

The multimedia principle is a derived finding from this architecture that considers the processing of new information in working memory (Mayer, 2012). It suggests that acquiring new information in long-term memory is enhanced when extraneous text and graphic information (i.e., seductive details) are removed from a computer-based multimedia lesson (Fiorella & Mayer, 2021; Moreno & Mayer, 2000). Apparently, seductive details demand attentional resources or cognitive load, reducing the processing of the information that needs to be learned (Bender et al., 2021). This effect is commonly observed in students who have no prior knowledge of the material (Sanchez & Wiley, 2006). However, it is still unclear how seductive details interact with prior knowledge (Mayer & Jackson, 2005; Wang & Adesope, 2016), or if these effects occur in ecologically valid conditions of online learning. Consequently, this study introduces the literature on seductive graphics and prior knowledge, and the results of two studies involving learning materials in the field of mathematics.

Online learning and multimedia learning

Online learning involves delivering educational information through digital platforms aimed at facilitating the acquisition of knowledge and skills (Clark & Mayer, 2024). While online learning has been theorized and researched from multiple and varied theoretical approaches (e.g., Downes, 2022) in this work, it is assumed that the effectiveness of online learning depends on how the design and use of technology and instruction align with the goals of acquiring domain-specific knowledge and the characteristics of the student (Castro-Alonso et al., 2021; Chen et al., 2017). In this context, cognitive theory of multimedia learning is a solid instructional perspective that has been widely used for designing and researching digital environments.

This theory suggests that people learn better when learning materials include both text and graphics, rather than just using materials with text alone (Mayer, 2012, 2020). The three main assumptions are that people have two separated channels for visual/spatial material and auditory/verbal material (Sadoski & Paivio, 2013) that has a limited processing capacity (Sweller, 2024), and should actively process relevant information to construct a coherent mental representation (Fiorella, 2023). From this perspective, online learning can be more effective when it guides students in selecting relevant information from a multimedia lesson, encourages the creation and organization of a mental representation in working memory, and promotes its integration into long-term memory. Relevant information (i.e., text and graphics) imposes an intrinsic load on working memory, while task-unrelated information (e.g., seductive images) imposes an extraneous load. Since extraneous load hinders learning, it should be minimized as much as possible (Mayer, 2019).

Seductive graphics

Not all information included in multimedia lessons is equally effective. According to the coherence principle, people comprehend and learn more when graphics, words, sounds, and symbols that are unrelated to the information being learned are excluded (Garner et al., 1989; Lehmann & Seufert, 2017; Mayer et al., 2008). Regarding graphics, Sung and Mayer (2012) have defined three types. *Instructional graphics* are external representations that facilitate understanding of the information, increase cognitive interest, and are directly related to the learning goal (i.e., they impose intrinsic cognitive load) (Harp & Mayer, 1997). For example, a lesson on calculating the volume of cylinders presents an image of a cylinder along with words pointing out the base and height.

On the other hand, *seductive graphics* are information elements unrelated to the learning goal and impose extraneous cognitive load. They are highly captivating, energizing, and evoke emotions, but they can consume working memory resources to the point of reducing attention to the relevant information, causing extraneous cognitive load (Sundararajan & Adesope, 2020). For example, a lesson about cylinders includes an image from the popular news showing a vendor throwing a cooking gas cylinder from a truck at a robber. *Decorative graphics* are also information elements unrelated to the learning goal and also impose extraneous cognitive load, but they are intended to be cognitively neutral, increase situational interest, make the presentation visually appealing, and create a pleasant tone (Schneider, Dyrna, et al., 2018). For example, a lesson on cylinders includes an image of natural landscapes such as a beach or a forest.

Most studies indicate that students who learn with seductive and decorative graphics score lower on performance tests compared to students who learn without these graphics (Mayer, 2019; Noetel et al., 2021; Rey, 2012; Sanchez & Wiley, 2006; Sundararajan & Adesope, 2020). The theoretical explanation is that seductive details induce extraneous processing in working memory (i.e., they distract, interrupt, or divert attention), leaving few resources available to construct a mental representation of the material and integrate it with knowledge retrieved from long-term memory (Bender et al., 2021; Mayer, 2020).

The use of seductive details seems to be justified from an emotive-motivational perspective (Kintsch, 1980; Renninger & Hidi, 2016). These perspectives advocate for the inclusion of phrases, graphics, and even unrelated sounds that, although unrelated to the learning goal, increase interest in the learning materials. However, the existent research suggests that seductive details may be beneficial under specific conditions, such as high pressure (Fries et al., 2019) or emotional arousal (Schneider, Wirzberger, & Rey, 2018).

Regarding the field of mathematics, to the best of our knowledge, there are very few studies on seductive and decorative details, and none conducted under the ecological conditions of online learning. For example, Fries et al. (2019) examined seductive details in a video on matrix properties under high and low-pressure conditions with 259 students. In the low-pressure condition, seductive details resulted in lower performance on the final test compared to those who learned without seductive details. However, no performance differences were found under high-pressure conditions. Furthermore, a recent meta-analysis (Sundararajan & Adesope, 2020) reported a surprisingly positive effect (g = 0.42) of seductive details in math and statistics materials. This analysis only involved 288 students from two experiments. The findings regarding decorative graphics also appear to be inconclusive (Lindner, 2020; Magner et al., 2014; Mikheeva et al., 2021). Apparently, decorative graphics seem to have the advantage of reducing math anxiety or generating situational interest that could promote learning (Park et al., 2005).

Prior knowledge

Novice and advanced students exhibit different performance on a task due to the type of knowledge they possess (Kalyuga, 2021; Richter et al., 2021; Zambrano R. et al., 2019). It seems to be more effective for novices to receive high support and guidance with appropriate integration of text and graphics (Hoogerheide et al., 2019). However, the effectiveness of these materials is reversed when students have relevant knowledge of the material in long-term memory (i.e., advanced students) (Jiang et al., 2023). Advanced students perform better than novices, probably because they retrieve a large amount of relevant information from long-term memory without being limited by working memory constraints (Kalyuga, 2021). However, the performance of these students may be compromised when they receive materials that incorporate a high level of support and guidance that they do not need. This result is referred to as the expertise reversal effect (Jiang et al., 2023; Kalyuga et al., 2003). Therefore, multimedia design for advanced students should avoid redundant images and words (i.e., already known information) and progressively increase the level of material complexity (Kalyuga, 2021).

The greater cognitive capacity of advanced students may reduce the extraneous cognitive load associated with seductive and decorative details (Korbach et al., 2016; Mikheeva et al., 2021; Sanchez & Wiley, 2006; Sundararajan & Adesope, 2020). However, there is very little empirical research on this relationship. For example, Magner et al. (2014) studied the effect of decorative details on performance in tests of near and far transfer in basic geometry (e.g., parallel lines, complementary angles, sum of angles, vertical angles). It was found that novices learned more with materials without decorative details than with them in the near transfer tests. However, advanced students learned more with the decorative details than without them in the same tests. In the delayed transfer tests, the advanced students performed better than the novices, and no interaction effects were found.

Wang and Adesope (2016) compared three types of materials (i.e., without seductive details, seductive details at the beginning, or seductive details at the end of the lesson) in geography materials (i.e., earth formation). It was found that novices without seductive details had higher performance than those who learned with the other materials. However, advanced students learned more without seductive details and with seductive details at the end than with seductive details at the beginning of the lesson. Fries et al. (2019) also examined the effect of prior knowledge, but in interaction with learning pressure. When students are novices, the inclusion or omission of seductive details did not affect learning under low pressure. However, in the high-pressure condition, novices learned more with seductive details than without them. These factors did not produce different results in advanced students. The results seem to support partially the hypothesis that learning with decorative and seductive images imposes extraneous processing on working memory only in novice students

(Korbach et al., 2016). However, it is unknown whether these results are consistent in the domain of mathematics and under the ecological conditions of online synchronous education.

The present study

The present study aimed to examine the coherence principle in online mathematics learning. In online synchronous sessions, many factors come into play that are not present in laboratory studies or controlled classroom conditions. Therefore, the research question was whether a multimedia lesson delivered through synchronous classes with instructional graphics improves mathematics learning outcomes compared to lessons with seductive graphics or without graphics. A second question was whether prior knowledge (i.e., novice and advanced students) moderates the learning outcomes.

EXPERIMENT 1

The purpose of Experiment 1 was to test the following hypotheses: learning with instructional graphics fosters a higher performance, lower mental effort, and higher efficiency (h1) than learning with seductive graphics. Additionally, learning without illustrations fosters a higher performance, lower mental effort, and higher efficiency (h2) than learning with seductive graphics.

Method

Participants

An a priori power analysis with a power .8 and a medium effect size .06 (Field, 2024) revealed that 156 participants would be sufficient to reliably test our hypotheses. The study involved 156 Ecuadorian students enrolled in a public school in Rumiñahui, as part of their mathematics curriculum. However, two students were unable to complete the study. Eighty males and 74 females participated, with an average age of 14.18 (*SD* = .80). The participants had not received prior instruction on the topic under study (i.e., geometric shapes), as confirmed by the pre-test during which they were unable to solve any tasks and selected the option “I don't know”. Academic compensation was provided to students for their participation in the study during their mathematics class. Moreover, the educational institution authorities and parents were duly informed about the study and provided necessary authorization.

Design and procedure

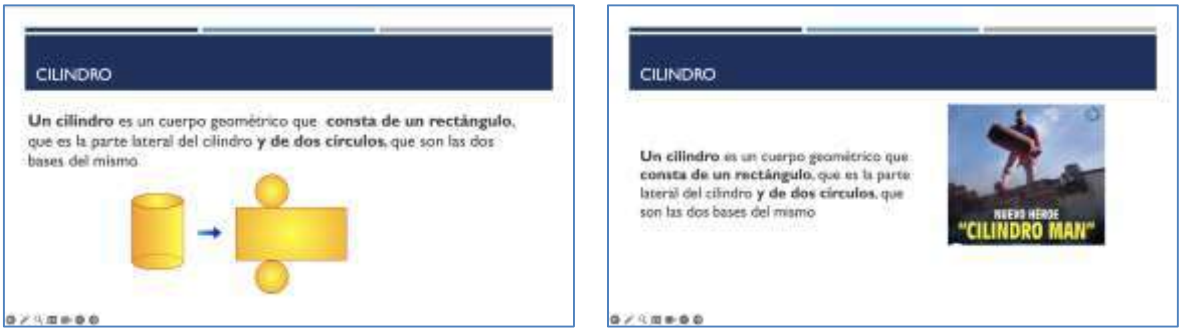
The study design featured three graphic conditions: instructional graphics, seductive graphics, and no graphics, and were conducted in a 45-min session. The students were randomly assigned to the conditions and the session was implemented by one of the authors. Firstly, each student was asked to complete a 10-min prior knowledge test. Secondly, the groups were created according to the condition, and each group used the Microsoft Teams platform. Thirdly, each student, under their respective conditions, received a 20-min multimedia lesson on calculating the volume of geometric shapes, with only the graphical representation differing. Finally, students were asked to complete a 10-min questionnaire to assess the acquired knowledge.

Materials

The entire experiment was conducted on Microsoft Teams. Electronic quizzes were used for the tests, and the presentations were made in PowerPoint. The learning material was mathematics-related, specifically about the volume of solid objects, and consisted of 13 timed slides under the control of the instructor. The material had approximately 1000 characters and was structured with text accompanied by instructional graphics, seductive graphics, or no graphics (Figure 1). All pictures were removed in the no graphic condition.

Figure 1

Sample of materials with instructional (a) and seductive graphic (b)



a b

Measures

Performance. Performance was measured before and after the multimedia presentation with the same knowledge test. It consisted of 6 multiple-choice questions covering the learning material. Each question had four options, and each option was scored between 1 and 4 points based on the level of complexity of the response. For example, the question 'What is the volume of a prism with a height of 5 cm and a base area of 10 cm?' was worth 1 point for correctly multiplying to obtain the volume. The question that asked to find the volume of a hexagonal prism with a base edge of 6 m, an apothem of 5.2 m, and a height of 27 m, was worth 2 points because it required two steps: calculating the base area and performing the multiplication. A 4-point question was 'Find the diameter of the circular base of a cylindrical water tank measuring 3 m in height and 1 m in diameter'. 'If you wanted to fill it halfway, how many liters of water would it hold?' In this case, four steps were required: calculating the base area, calculating the volume of the body, converting the measurement, and dividing the value in half.

Mental effort. Cognitive load was measured using the mental effort scale after each learning task using a 9-point subjective mental effort scale (Van Gog & Paas, 2008). The scale varied from 1 (very, very low mental effort) to 9 (very, very high mental effort).

Cognitive efficiency. Efficiency (E) refers to the quality of learning because of combining performance and mental effort (Van Gog & Paas, 2008). High efficiency refers to achieving a high performance while expending relatively low mental effort. Conversely, low efficiency implies achieving relatively low performance outcomes despite investing considerable mental effort. Efficiency was determined by standardizing the task performance and mental effort scores of each participant. Specifically, z-scores were computed for both effort (R) and performance (P) for each participant, and the formula $E = [(P - R)/2^{1/2}]$ was used.

Results

The data were analyzed using a one-way analysis of variance (ANOVA). The independent variable was the type of graph (instructive graph, seductive graph, and no graph), and the dependent variables were performance, mental effort, and efficiency in the retention tests (Table 1). A significance level of .05 was used for the analysis, along with ηp^2 as a measure of effect size, with values of .01, .06, and .14 corresponding to small, medium, and large effects, respectively (Field, 2024).

Table 1
Descriptive statistics

Learning condition	*M*	*SD*
Performance		
Instructive graphics	6.14	2.34
Seductive graphics	1.94	1.41
No graphics	4.49	2.18
Mental effort		
Instructive graphics	20.51	5.03
Seductive graphics	22.08	4.95
No graphics	20.06	5.36
Efficiency		
Instructive graphics	.57	.99
Seductive graphics	-.77	.80
No graphics	.19	1.02

Regarding performance, the ANOVA revealed a statistically significant difference, $MSE = 4.09$, $F(2, 151) = 55.12$, $p < .001$, $\eta p^2 = .42$. Post hoc Bonferroni tests showed that the material with instructive images resulted in higher performance compared to seductive images ($p < .001$) and no images ($p < .001$). Additionally, the material without images resulted in higher performance than the material with seductive images ($p < .001$).

Concerning mental effort, the ANOVA did not show significant differences among the three learning conditions, $MSE = 26.23$, $F(2, 151) = 2.19$, $p < .001$, $\eta p^2 = .03$, suggesting that the groups invested an equal level of cognitive load. Finally, regarding cognitive efficiency, the ANOVA revealed a statistically significant difference, $MSE = .89$, $F(2, 151) = 26.97$, $p < .001$, $\eta p^2 = .26$. Post hoc Bonferroni tests suggested that the material with instructive images was more efficient than the material with seductive images ($p < .001$), and equally efficient as the material without images ($p = .13$). It was also found that the material without images was more efficient than the material with seductive details ($p < .001$).

Discussion

This experiment aimed to test whether students who learn with instructional graphics achieve better performance, experience less mental effort, and consequently are more cognitively efficient than those who study with seductive graphics (h1). This hypothesis was partially supported, as our data only supported the hypotheses of performance and efficiency. Overall, our results are consistent with previous findings on the advantage of learning with instructional graphics (Moreno & Mayer, 2000). It appears that instructional graphics imposed intrinsic load that induced the creation of a more coherent mental representation of material, which resulted in better retention of information in long-term memory.

The result regarding mental effort suggests that the material that included instructional graphics imposed a similar mental load as the material with seductive graphics. This does not imply that both types of graphics induced similar processing in working memory. It is likely that decorative graphics increased cognitive interest, which led to an increase in cognitive processes associated with understanding the material (Bender et al., 2021). On the other hand, seductive graphics may have consumed high attentional resources with the disadvantage of interrupting or diverting attention from the construction and acquisition of a coherent mental model (Park et al., 2011). The result of efficiency revealed that the combination of performance and mental effort is better for instructional graphics. In other words, although both types of materials impose a similar cognitive load, learning with instructional graphics is more cognitively efficient in terms of academic achievement.

Our second hypothesis was that students who learn without graphics would have higher levels of performance, lower mental effort, and higher efficiency (h2) than those who learn with seductive graphics. Our results partially support this expectation, as evidence was found only for performance and efficiency. We expected that the removal of seductive graphics would reduce extraneous mental processing (i.e., extraneous cognitive load), resulting in lower demands on working memory resources (i.e., lower mental effort scores). However, our results suggest that the removal of interesting graphics, while significantly improving performance, does not imply a reduction in information processing load. An alternative explanation could be that mental load was a mediating factor (Park et al., 2011). That is, the essential information of the material imposed a high intrinsic cognitive load associated with the elaboration of a mental model of the material, while the seductive details imposed high mental resources, perhaps due to insufficient time to comprehend the material.

EXPERIMENT 2

The purpose of this experiment was to test hypotheses regarding prior knowledge. When students are novices, instructional graphics promote better learning outcomes than seductive graphics (h1); similarly, decorative graphics foster superior learning outcomes than seductive graphics (h2). However, when students are advanced, instructional, and decorative graphics produce similar learning outcomes as instructional graphics (h3).

Method

Participants

An a priori power analysis with a power .8 and a medium effect size .06 was performed (Field, 2024) which indicated that 158 participants would be sufficient to reliably test our hypotheses. Participants were 163 Ecuadorian students from public education, 75 males and 88 females, with a mean age of 12.99 years (SD = .97). The activities were conducted as part of the mathematics subject. The institution authorities and parents were provided with information about the study and gave their authorization for participation. Additionally, all participants received 10 points in their subject as compensation for their effort.

Two groups from the upper basic education level were recruited. One had not received instruction on vectors because this topic was excluded during the COVID pandemic period (i.e., novice students), and the other had already received instruction on vectors as part of the preparation for secondary education (i.e., advanced learners). The ANOVA revealed that novice students (n = 79, M = 2.30, SD = .70) had lower prior knowledge than advanced students before the experiment (n = 84, M = 4.38, SD = .70, MSE = .37, $F(1, 157)$ = 452.13, p < .001, ηp^2 = .74). No difference was found between students who learned with instructional graphics (n = 58, M = 3.8, SD = 1.17), decorative graphics (n = 52, M = 3.33, SD = 1.22), and seductive graphics (n = 53, M = 3.01, SD = 1.20, MSE = .37, $F(1, 157)$ = 2.97, p = .054, ηp^2 = .03). These results suggested that prior knowledge was the differentiating factor among the participants.

Design and procedure

A 2 (prior knowledge: novices vs. advanced) x 3 (type of graphics: instructional, decorative, and seductive) factorial design was used. The dependent variable was performance in a specific domain: vectors. Participants were randomly assigned to all study conditions.

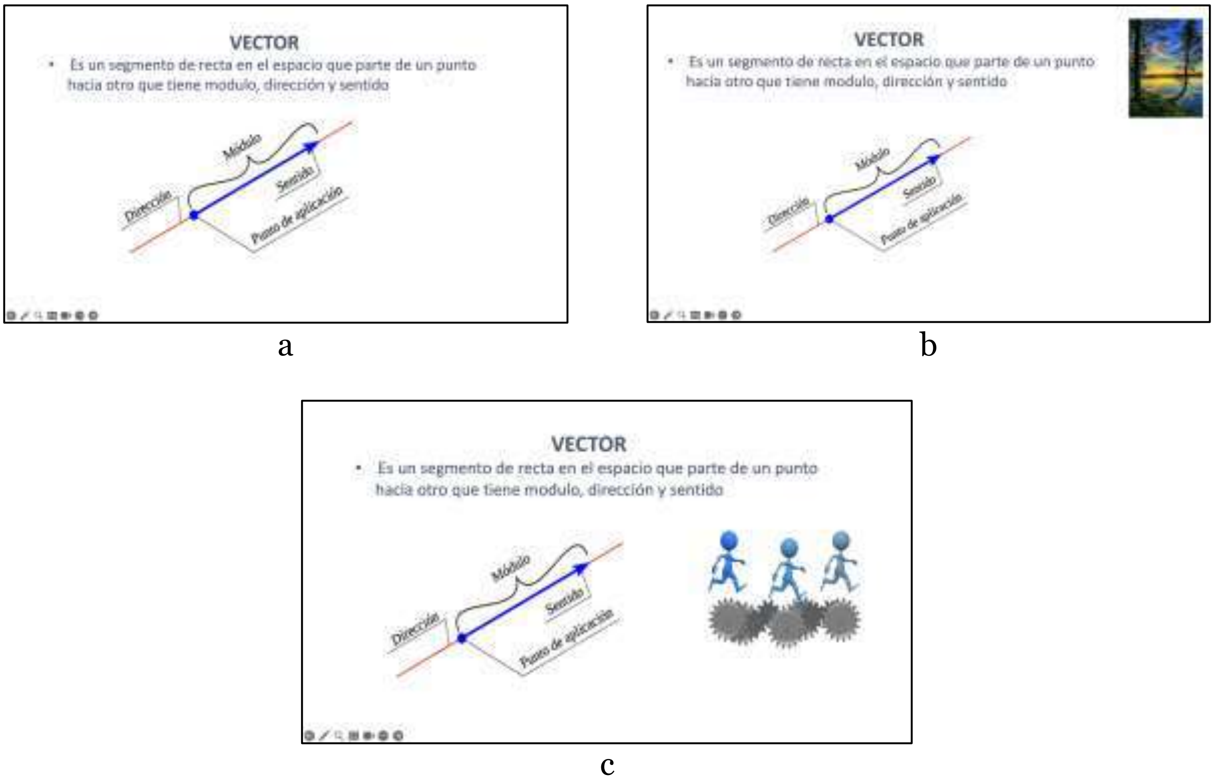
The procedure was administered by one of the authors and two teacher assistants. The advanced group underwent a retrieval practice session on vectors one day before the experiment, overseen by an instructor who ensured evocation of the topic through questioning and testing. On the day of the experiment, all students were instructed to access the Zoom video conferencing platform and adhere to the teachers' directives throughout the class. Subsequently, participants individually completed a 7-minute pretest assessing prior knowledge, comprising five multiple-choice items. Following the pretest, participants were allocated to their respective study conditions using Zoom breakout rooms. Assigned teachers for each group delivered a multimedia lesson based on the study condition and directed participants to review it, lasting approximately 45 minutes. Finally, participants underwent a 7-minute posttest featuring five multiple-choice items. Upon completing all tests, students were thanked for their participation.

Materials

The entire experiment was conducted on the Zoom platform. Electronic questionnaires were used for the tests, and the presentations were created in PowerPoint. The learning material was about mathematics and consisted of 12 slides with identical text describing the fundamental concepts of vectors: definition of a vector, characteristics, magnitudes, elements, and an exercise. In the instructional graphics version (Figure 2), 11 images were added in a section of the lesson that described the characteristics and components of vectors. In the seductive graphics version, 13 animated GIF images unrelated to the lesson's goal were added. And in the decorative graphics version, landscape images that did not correspond to the lesson's goal but were not visually appealing were added.

Figure 2

Sample of materials with instructional (a), decorative (b) and seductive graphics (c)



Performance measurement

Performance measurements were conducted before (i.e., pretest) and after (posttest) the learning phase. Prior knowledge of the learning materials was measured using a five-question multiple-choice questionnaire. Each question was scored with 1 point. The knowledge acquired in the learning phase was measured using another questionnaire with five multiple-choice questions, each worth one point. The questionnaires were electronic, delivered to each student via a virtual platform, and students were instructed to keep their cameras on. Additionally, a digital timer was used to control the response time for each questionnaire.

Results

The data were analyzed using an analysis of variance (ANOVA): 2 (prior knowledge: novices vs. advanced) x 3 (types of graphics: instructional, decorative, and seductive). The dependent variable was performance in the retention tests (Table 2). A significance level of .05 was used for the analysis, along with ηp^2 as a measure of effect size, with values of .01, .06, and .14 corresponding to small, medium, and large effects, respectively (Field, 2024).

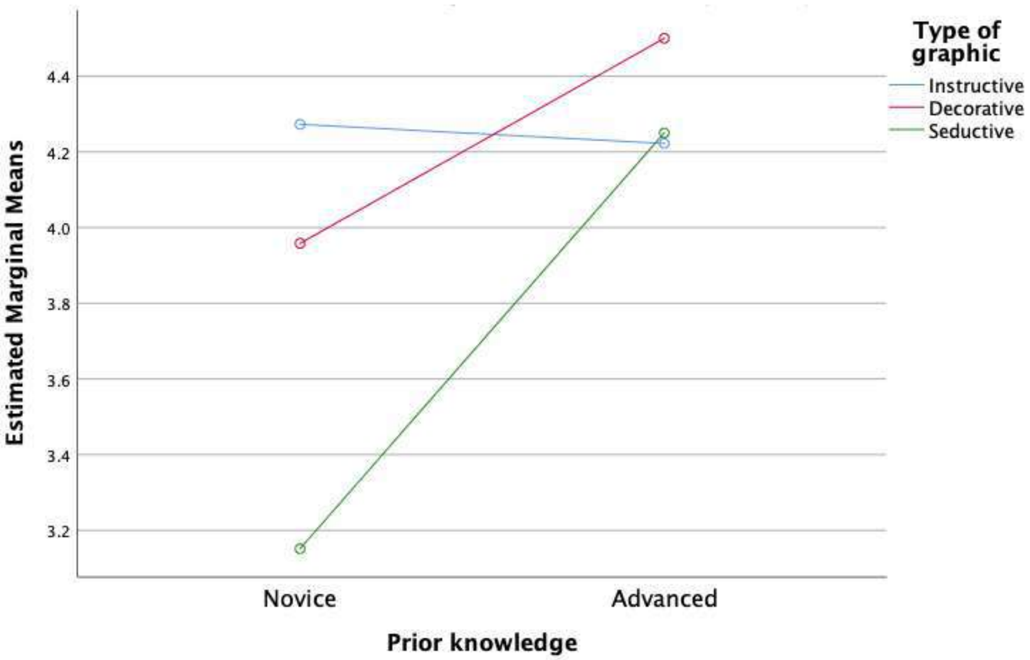
Table 2
Descriptive results

Learning condition	*M*	*SD*
Novice		
Instructive graphic	4.27	.77
Decorative graphic	3.96	1.04
Seductive graphic	3.15	1.15
Advanced		
Instructive graphic	4.22	.80
Decorative graphic	4.50	.75
Seductive graphic	4.25	.85

The ANOVA revealed a significant main effect for prior knowledge condition, suggesting that advanced students (M = 4.32, SD = .79) performed better than novice students, M = 3.71, SD = 1.12, MSE = .83, $F(1, 157) = 13.16$, $p < .001$, $\eta p^2 = .08$. The ANOVA also showed that the main effect of graph types was significant, indicating a difference between those who learned with instructional graphs (M = 4.25, SD = .12), decorative graphs (M = 4.23, SD = .13), and seductive graphs (M = 3.70, SD = .13, MSE = .83, $F(2, 157) = 5.91$, $p = .003$, $\eta p^2 = .07$). A post hoc Bonferroni analysis revealed that instructional graphs ($p = .008$) and decorative graphs ($p = .012$) were superior to seductive graphs.

The ANOVA also revealed a significant interaction between the main effects, MSE = .83, $F(1, 157) = 5.181$, $p < .007$, $\eta p^2 = .06$ (Figure 3). The post hoc Bonferroni analysis showed that when students have lower prior knowledge, learning with instructional graphs ($p < .001$) and learning with decorative graphs ($p < .004$) results in better performance than learning with seductive details. There was no difference between instructional and decorative graphs ($p = .73$; $\eta p^2 = .13$). When students are advanced, there was no difference between learning with instructional graphs and seductive details ($p = 1.00$), between instructional and decorative graphs ($p = 1.00$), or between instructional and seductive graphs ($p = .69$; $\eta p^2 = .01$).

Figure 3
Interaction between prior knowledge and graph type



Discussion

The second experiment aimed to examine the effect of decorative details and the mediating role of prior knowledge. The first hypothesis was that for novices, instructional graphs would result in better performance than seductive graphs. Our data provide evidence for this expectation, which is consistent with the first experiment. Instructional graphs guided the selection of relevant information and induced the formation of a more coherent mental representation of the study material, resulting in greater knowledge acquisition. Instructional graphics appear to have enhanced both the comprehension and acquisition of material information in long-term memory (Mayer, 2020).

Our results also support the second hypothesis that decorative graphs lead to better learning outcomes than seductive graphs. Decorative details, although not designed to contribute to the learning goal, may have increased situational interest in the material (Magner et al., 2014), which may have induced extraneous load during processing material information. It appears that decorative graphs created a more productive emotional condition than the emotional condition associated with seductive details (Mayer & Estrella, 2014; Plass & Kalyuga, 2019).

The third hypothesis was that instructional and decorative graphs would produce similar learning outcomes to seductive graphs when students are advanced. Our results support this prediction. Advanced students, as suggested by the main effect of prior knowledge level, learned more than novices, perhaps due to their prior cognitive advantage. It seems that this advantage reduced the negative impact of seductive details (Fries et al., 2019). This finding is consistent with previous studies suggesting that high prior knowledge is a factor that reduces the effects of cognitive load and multimedia learning (Fiorella & Mayer, 2021; Mayer, 2020; Mayer & Fiorella, 2022; Wang & Adesope, 2016).

This result is explainable by the cognitive load theory (Sweller, 2024). While working memory is highly limited when students process new information, there are no cognitive limits when processing already known and organized information in long-term memory. Once the information has been acquired (i.e., this is the purpose of teaching), students expand their cognitive capacities with which they can better leverage the information they encounter in the external environment (e.g., study materials) to generate appropriate actions for that environment. In other words, advanced students utilized their extended cognitive capacity and prior cognitive structures to avoid seductive information elements and identify the most relevant information elements of the study material for more effective acquisition (Sanchez & Wiley, 2006).

GENERAL DISCUSSION

Online education is made possible by the development of technologies and information presentation formats. The easy access and management of current digital tools allow for the creation of highly engaging environments that can be incorporated into online courses (Miralles Martínez et al., 2019). However, the limited cognitive capacities of the students are not different from what they were before the advent of current technological developments (Nairne, 2022). Therefore, it is crucial that educational environment designs, to be effective in terms of academic achievement, consider how multimedia elements affect the processing of the information that needs to be learned. The present study aimed to explore the principle of coherence in online mathematics learning.

The first study explored whether a multimedia lesson with instructional graphs improves online mathematics learning outcomes compared to lessons with seductive graphs or no graphs in a synchronous videoconference session. These results are in line with previous studies on the effect of instructional and seductive details (Garner et al., 1989; Rey, 2014; Sundararajan & Adesope, 2020). Materials with instructional graphs and without graphs were more effective because they appeared to influence the creation of a more coherent mental representation of the mathematics content in online learning conditions. The results of the mental effort measurement suggest that even materials without graphs impose a cognitive load equivalent to instructional and seductive graphs. However, the equal mental effort resulted in lower efficiency in materials with seductive details.

The second study examined whether prior knowledge (i.e., novice and advanced students) moderates learning outcomes. The analyses showed that the effect of seductive and decorative details are relevant for novice students, which is consistent with previous studies (Rey, 2012; Sundararajan & Adesope, 2020; Wang & Adesope, 2016). It seems, the inclusion of instructional and decorative graphs contributes to the elaboration of a better mental representation of the mathematics material compared to material with seductive graphs. The instructional graphics were designed and utilized to complement verbal and numerical information, thereby imposing intrinsic cognitive load during the processing of the material. It is probably that this load improved comprehension and fostered a better acquisition in long-term memory.

The positive effect of decorative graphs could be interpreted from the cognitive-emotional theory of multimedia learning that highlights the emotional aspects of cognitive processing (Mayer & Estrella, 2014; Plass & Kalyuga, 2019). Decorative graphics may have increased the student's motivation and interest to understand the essential material and, thus, foster deeper learning processes leading to better learning outcomes (Magner et al., 2014; Mikheeva et al., 2021). The results for advanced students were also consistent with previous literature (Bender et al., 2021; Fries et al., 2019). It seems that advanced students leverage their prior schemas and extended cognitive capacity to avoid seductive elements and focus on the relevant elements of the material (Sanchez & Wiley, 2006).

Similar to the first experiment, the results of the second study were obtained through digital presentations of mathematics using synchronous streaming programs commonly used in current online education. Additionally, it is common for students in online classes to have varied levels of prior knowledge about the learning material. Therefore, these results could be generalized to online learning conditions that require mathematical processing for both novice and advanced students.

In conclusion, the negative effect of seductive details inhibits mathematics learning in multimedia classes via video conferencing. Multimedia online or synchronous lessons that include instructional graphics enhance student performance compared to classes with seductive graphics. Likewise, decorative graphics foster more learning compared to seductive graphics, perhaps because they increase motivation and interest. However, the superiority of these graphics was only observed among novice students. When students already have prior knowledge of the material, seductive graphics are not relevant as they appear to be ignored by advanced students. (Sanchez & Wiley, 2006).

One limitation of our studies was that independent cognitive load measurements (i.e., intrinsic or associated with essential material, and extraneous or associated with seductive/decorative material) were not included. Although the experiments were conceived from the perspective of cognitive load and the first study included a measurement of mental effort, there are currently other methods to estimate the cognitive load associated with learning material (Skulmowski, 2023). An additional limitation is that our study did not consider specific sources of extraneous load, such as students' cameras, static profile images, ambient sounds, among others, which are common in videoconference platforms such as Microsoft Teams or Zoom.

Future studies should replicate these experiments by including, for example, measurements of eye movements while students work online on computers (Bender et al., 2021; Stark et al., 2018). Another limitation was the lack of transfer of learning assessments. While it is unclear whether the results of transfer of learning assessments are a good indicator of acquired knowledge because schemas do not easily generalize to different conditions even within the same domain (Tricot & Sweller, 2014), future studies could include measurements of the application of mathematical concepts in similar conditions, either immediately or days after multimedia teaching (i.e., long-term knowledge).

These studies have clear implications for educational practice. The design of multimedia materials and online environments should consider the capabilities and limitations of both novice and advanced students. This implies incorporating prior knowledge tests and adapting multimedia materials accordingly. Current platforms often include quiz modules that can be configured to guide students in selecting materials based on their performance scores. For instance, it could be established that if a student does not attain a certain level in a math topic, materials featuring instructional graphics should be recommended.

Another educational implication is to use seductive details cautiously, particularly for advanced students. This work and previous literature consistently indicate that advanced students appear to be less affected by seductive graphs. It may be beneficial to provide math materials with some seductive graphs, or alternatively, to offer more complex materials (i.e., new information) with minimal decorative details. Given the potential challenges in achieving high performance standards in mathematics, leveraging the higher cognitive capacity of advanced students may be advantageous in advancing through the educational program with materials designed to evoke positive emotions. (Plass & Kalyuga, 2019).

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Evaluation of contextual variables in the implementation of the Flipped Classroom methodology in secondary education

Evaluación de variables contextuales en la implementación de la metodología Flipped Classroom en educación secundaria

José Luis Estévez-Méndez - *Universidad a Distancia de Madrid, UDIMA (Spain)*
José Luis Díaz Palencia - *Universidad a Distancia de Madrid, UDIMA (Spain)*
Almudena Sánchez Sánchez - *Universidad a Distancia de Madrid, UDIMA (Spain)*
Julián Roa González - *Universidad a Distancia de Madrid, UDIMA (Spain)*

ABSTRACT

This study focuses on the Flipped Classroom (FC) methodology in secondary education, evaluating its impact in relation to different contextual variables of the educational system. The hypotheses explore whether variables such as the type of educational institution, the teacher's area of expertise, their experience and training, age, the classroom layout and the academic semester within the school year, impact the adoption of the FC. For this purpose, information was collected by means of a questionnaire that contemplated aspects of students, educational institutions and teachers, in addition to observing the use of FC in classrooms. The questionnaire contains predominantly closed questions with the idea of encouraging a quantitative study methodology. After analyzing the results, statistically significant differences were found in the use of FC between private and subsidized centers versus public ones. The age of the teacher also proved to be an influential factor, with greater adoption of FC among teachers under 40 years of age. The teaching specialty of knowledge was also a significant factor, with greater use of FC in the areas of English Language and Professional Training compared to others such as Mathematics, Spanish Language and Literature or Biology. These results indicate that the implementation of FC is uneven, influenced by the type of school, the age of the teachers and their specialization. Our research underlines the need to provide adequate resources and continuous training, especially in public schools, to foster the equitable adoption of innovative educational methodologies such as FC.

Keywords: open education; active methodologies; flipped classroom; quantitative research.

RESUMEN

El presente estudio se centra en la metodología Flipped Classroom (FC) en la educación secundaria, evaluando su impacto en relación con distintas variables contextuales del sistema educativo. Las hipótesis abordan si el tipo de centro educativo, especialidad docente, experiencia y formación del profesorado, su edad, la disposición de las aulas y la relación del uso de FC con el semestre académico, influyen en la adopción de FC. Para ello, se recopiló información mediante un cuestionario que contemplaba aspectos de los estudiantes, los centros de prácticas y los docentes, además de observar el uso de FC en el aula. El cuestionario contiene predominantemente preguntas cerradas con la idea de fomentar una metodología de estudio cuantitativa. Tras el análisis de resultados, se encontraron diferencias estadísticamente significativas en el uso de FC entre centros privados y concertados frente a los públicos. La edad del docente también resultó ser un factor influyente, con una mayor adopción de FC entre docentes menores de 40 años. La especialidad docente también supuso un factor significativo, dándose un mayor empleo de FC en las áreas de Inglés y Formación Profesional en comparación con otras como Matemáticas, Lengua y Literatura o Biología. Estos resultados indican que la implementación de FC tiene un carácter desigual, influenciada por la tipología del centro educativo, la edad del profesorado y la especialización. Esto subraya la necesidad de proporcionar recursos adecuados y formación continua, especialmente en centros públicos, para fomentar la adopción equitativa de metodologías educativas innovadoras como el FC.

Palabras clave: educación abierta; metodologías activas; flipped classroom; investigación cuantitativa.

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INTRODUCTION

In recent years, and through the emergence of new technologies and their application in education, new methodological currents have emerged that facilitate learning in an active and participatory way (Cárdenas et al., 2023). Thanks to these possibilities, students have come to play a leading role in their own teaching-learning process, leading to the emergence of more open and flexible educational environments (Berenguer, 2016).

One of the emerging methodologies that has the student as the main axis has been the so-called "Flipped Classroom", hereinafter "FC" and is defined as one in which students carry out a process of research and study on specific content outside the educational center, which is subsequently worked on practically in the classroom by solving problems, resolving doubts or carrying out practical work (Pozuelo, 2020).

This methodology, applicable to all curricular areas of the different educational levels (Blasco et al., 2016), allows students to adopt their own learning pace and enables teachers to individualize the teaching process by devoting a greater amount of time to the students who require it most, taking into account their interests and needs (Mohanty & Parida, 2016; Aguilera-Ruiz et al., 2017), thus facilitating the personalization of teaching (La Marca, 2020). Furthermore, according to studies by González-Fernández and Carrillo (2016) the use of FC in combination with other methodologies, such as cooperative learning, are highly recommended. It is important to keep in mind that the application of FC is accompanied by a series of teaching skills that are unavoidable to ensure correct implementation, such as the creation of audiovisual content, activity design and technological skills (Yeh, 2022).

According to some studies, the application of the FC methodology has a positive impact that influences, at the psycho-educational level, several emotional and cognitive variables (Sánchez-Soto & García Martín, 2023). In terms of emotional variables, we find aspects such as motivation, participation, collaboration or satisfaction of the individual, and in terms of cognitive variables, performance, creativity and the individual's capacity for critical thinking or autonomy are identified.

In contrast, other researchers have not identified statistically significant differences between the use of new active methodologies versus traditional ones in terms of aspects such as degree of satisfaction or self-assessment of knowledge by students (Kim, 2018; Morgan et al., 2015), identifying the possibility that the modifying variables are the types of technologies used, the amount of time available to students or school organization.

Regarding the students' perception of the use of CF in the classroom, some studies, such as those of Pozuelo (2020), show that positive bonds are created between students and teachers, considering it an effective and useful factor. These results are in line with other authors who point out the need to increase, in this type of methodology, the levels of co-responsibility and commitment in both students and teachers (Del Arco Bravo et al., 2019). Along the same lines, Espada et al. (2020), highlight a better use of time, a positive assessment of the flexibility provided by the use of this methodology, a greater involvement and enjoyment with the training process and a better adaptability to the learning needs of students.

The successful use of FC depends on a minimum degree of teaching digital competence that allows its correct development, which is affected by factors such as age, gender, degree of experience or continuous training (Çebi & Reisoglu, 2020). This fact possibly explains the disparity in the results of different scientific studies that reach conflicting conclusions regarding the real effectiveness of this methodology (Galindo-Domínguez & Benzanilla, 2019). However, and in line with research related to the analysis of teachers' digital knowledge, although digital equipment and infrastructures are not currently a problem (Gómez, 2016), a low level of teachers' digital competencies has been identified, with only 19 % of teachers having a high level of digital competencies (Raposo et al., 2020; Andía-Celaya et al., 2020).

In the context described, we have sought to analyze the influence of factors related to the teachers themselves, as well as structural and organizational factors of the center, these being the object of analysis of the present research. The results obtained after the collection and processing of data, the statistical-descriptive analyses and the study of the results obtained from students who have completed a period of compulsory internships in educational institutions during the master's degree in Teacher Training in Secondary Education at the Distance University of Madrid (UDIMA) are presented below.

In this sense, different variables have been taken into account, such as the area or specialty of knowledge in which the methodology is used, the type of institution, the age and years of experience of the teachers who have tutored the internships, the pedagogical training of the teachers and the types of spaces and resources used.

OBJECTIVES AND HYPOTHESIS

The general objective of this research is to analyze the influence of different contextual variables on the use of the FC methodology in compulsory secondary education. In order to evaluate the impact of the FC methodology in secondary education classrooms, several hypotheses have been formulated that consider contextual variables within the educational system in relation to this methodology.

- H1: The type of educational center (public, private, subsidized) does not significantly affect the frequency of use of FC.
- H2: The expertise in specific subject areas of secondary school teachers does not have a significant impact on the adoption of FC.
- H3: The years of teaching experience do not significantly determine the use of FC.
- H4: The pedagogical training of teachers does not significantly impact the adoption of FC.
- H5: The age of the teachers is not determinant in the adoption of FC.
- H6: The layout of the classrooms does not significantly affect the use of FC.
- H7: The use of FC does not vary significantly between the semesters of the 20/21 to 22/23 academic years.

We will delve into the study of each hypothesis, focusing on key aspects for future discussions. Details about the concepts employed to measure "the use of the methodology", including the evaluation scale, will be provided later.

METHODOLOGY

The importance of establishing a clear definition of FC, following Pozuelo (2020), is emphasized as a crucial step so that respondents can properly identify this educational methodology. The observation of three essential elements is highlighted:

the provision of audiovisual material by teachers for its use outside the classroom, the promotion of research and self-exploration by students through this material, and the dedication of class time to active participation activities, such as debates and clarification of doubts, after reviewing the audiovisual content.

This investigation has been conducted within a context of contemplation on the 180-hour training activities performed by Master's students in Teacher Education. Throughout their internships, these students shadow a currently practicing teacher, gaining insights into the educational dynamics of their assigned schools. They are required to maintain a detailed journal documenting: the activities they engage in; key information about both the educational institution and the supervising teacher; along with their reflections on teaching methodologies, time and space management, resources, and assessment practices observed. In addition, they are asked to complete a specially designed questionnaire for this study, which gathers data on the students' personal backgrounds (including their specific master's program, gender, age, and prior education) and details about the internship site (like its type, operating hours, geographic location, and socioeconomic context). The survey also probes into characteristics of the mentor teacher, including their age, educational background, and teaching competencies. Moreover, it seeks to gather data on the implementation of the FC approach within the classroom setting. The questionnaire primarily consists of closed questions with single-choice answers, allowing students to select from a list of provided options.

To design the questionnaire, the study dimensions were initially identified to establish key indicators, following the approach of Ruiz (2014). This formed the basis for creating clear and straightforward questions, avoiding negative phrases and judgments towards respondents, in line with Palou's recommendations (2011). Afterward, a group of multidisciplinary education experts reviewed the draft of the questionnaire, conducting an analysis according to procedures suggested by Palou (2011). This panel recommended changes to enhance the tool, ensuring that the questions aligned with the constructivist paradigm, praised by Marsh and Dunkin (1997) for its effectiveness towards the coherence and alignment of the questionnaire's objectives. Finally, the revised questionnaire was tested with teachers not involved in its creation, who assessed its relevance and suitability, allowing for further refinement of the tool before its final application.

Regarding construct validity, various techniques were employed. Bartlett's test of sphericity was applied, yielding significant results (X^2 (15) = 1056,366; p =< ,001), and the Kaiser-Meyer-Olkin (KMO) index reached a value of ,717, indicating an adequate correlation matrix according to Kaiser (1970). Additionally, a principal component analysis revealed a cumulative variance of 0,570 for the FC methodology, confirming the questionnaire's suitability to assess this factor. Internal consistency was verified through Cronbach's alpha coefficient, recording a value of 0,739 for the FC methodology, which demonstrates a satisfactory correlation among the items. Regarding reliability, in addition to Cronbach's alpha, it is noted that students complete a logbook during their internships. In this logbook, they record details and reflections on the FC, contributing to consistency between direct observations and questionnaire responses, ensuring reflective assessment.

The study's sample includes 1,139 Master of Education students from various specialties, who undertook internships from September 2020 to June 2023, providing data from 2,114 classrooms. This represents a significant sample compared to the estimated 130,000 classrooms in secondary, high school, and professional training in

Spain, offering national representativeness with a margin of error less than 3 %. Most data come from Andalusia, Catalonia, and Madrid. The gender distribution of the students is 58.82 % women and 41.18% men, with 77.35 % between 25 and 40 years old, 16.07 % over 40, and 6.58 % under 25 years old.

Once the data were collected, the following phases were followed for analysis:

1. Response consolidation: The study variable had five levels of gradual implementation based on the applicability of the methodology, which were coded as follows:

    - Value 1: I have not seen FC being part of the methodologies used (0 %).
    - Value 2: I have seen some use of videos and online materials but not meeting some of the FC characteristics (0 %).
    - Value 3: I have seen FC used on an occasional basis (<25 %).
    - Value 4: I have seen FC used in a significant number of sessions (>25 % and <75 %).
    - Value 5: I have seen FC used in the majority of sessions (>75 %).

2. Quantitative analysis: Descriptive statistics, such as contingency tables, were used to evaluate the implementation of the methodology based on the responses.
3. Non-parametric mean comparison: To identify significant differences between groups, we used non-parametric tests, specifically Kruskal-Wallis and Mann-Whitney tests. The appropriateness of these tests was based on the Kolmogorov-Smirnov test, which showed results less than 0.05, confirming the non-normal distribution of the data (Berger & Zhou, 2014).

RESULTS

The results are organized based on the percentage of time that teachers dedicate to the FC methodology in the classroom according to the coding Value 1 - 5. These results are segmented based on different independent variables according to the response options. These variables are:

- Subject areas or specialties: Biology and Geology, Physical Education, Professional Oriented Training, Geography and History, Spanish Language and Literature, English Language and Mathematics.
- Type of educational center: public, private, or subsidized.
- Teacher's age: less than 25 years, between 25 and 40 years (inclusive), more than 40 years.
- Years of teaching experience: Between 1 and 5 years (inclusive); between 6 and 10 years (inclusive); and more than 10 years.
- Teacher's pedagogical training: Teacher Training Certificate (former CAP in Spain), Master in Teacher Training, None, Other.
- Organization and types of educational spaces: Open Classroom, variable structure classroom, subject-specific classroom, classroom building, Other.
- Semester of methodology observation: Coded by indicating first or second semester (1S, 2S) followed by an underscore with the corresponding academic year (20_21, 21_22, 22_23).

In Tables 1 - 7, the information collected in our study is summarized. A review of the tables reveals significant differences in the adoption of the FC methodology based on various criteria, as outlined below.

Table 1

Usage of the FC methodology by knowledge specialty

Specialty	FC (Coded Variable) - Case counts (%)					Total
	1	2	3	4	5	
Biology and Geology	108 (47,0%)	56 (24,3%)	42 (18,3%)	14 (6,1%)	10 (4,3%)	230 (100%)
Physical Education	49 (32,5%)	30 (19,9%)	37 (24,5%)	26 (17,2%)	9 (6,0%)	151 (100%)
Professional Training	11 (23,9%)	12 (26,1%)	7 (15,2%)	9 (19,6%)	7 (15,2%)	46 (100%)
Geography and History	128 (35,1%)	66 (18,1%)	81 (22,2%)	60 (16,4%)	30 (8,2%)	365 (100%)
English Language	168 (36,8%)	91 (19,9%)	104 (22,8%)	68 (14,9%)	26 (5,7%)	457 (100%)
Spanish Language and Literature	102 (54,3%)	24 (12,8%)	30 (16,0%)	20 (10,6%)	12 (6,4%)	188 (100%)
Mathematics	382 (56,4%)	125 (18,5%)	93 (13,7%)	57 (8,4%)	20 (3,0%)	677 (100%)
Total	948 (44,8%)	404 (19,1%)	394 (18,6%)	254 (12,0 %)	114 (5,4%)	2114 (100%)

Analyzing the specialty of knowledge (see Table 1), the use of FC constitutes more than 25 % of the sessions (sum of the percentages in values 4 and 5) and is less in Mathematics (11.4 %), Spanish Language and Literature (17 %), and Biology and Geology (10.4 %). The methodology is used more in Physical Education (23.2 %), English (20.6 %), Geography and History (24.6 %), and Professional Oriented Training (34.8 %).

Table 2

Use of the FC methodology based on the type of educational institution

Type of institution	FC (Coded Variable) - Case counts (%)					Total
	1	2	3	4	5	
Subsidized	502 (43,6%)	216 (18,8%)	212 (18,4%)	153 (13,3%)	68 (5,9%)	1151 (100%)
Private	128 (43,5%)	56 (19,0%)	53 (18,0%)	36 (12,2%)	21 (7,1%)	294 (100%)
Public	318 (47,5%)	132 (19,7%)	129 (19,3%)	65 (9,7%)	25 (3,7%)	669 (100%)
Total	948 (44,8%)	404 (19,1%)	394 (18,6%)	254 (12,0%)	114 (5,4%)	2114 (100%)

Regarding the use of the FC methodology based on the type of educational institution (see Table 2), it is used less in public centers (13.4%) compared to private (19.3%) and subsidized (19.2%) centers.

Table 3

Use of the FC methodology based on the teacher's age

Age (years)	FC (Coded Variable) - Case counts (%)					Total
	1	2	3	4	5	
Less than 25	4 (28,6%)	4 (28,6%)	2 (14,3%)	4 (28,6%)	0 (0,0%)	14 (100%)
Between 25 and 40	237 (39,6%)	110 (18,4%)	125 (20,9%)	84 (14,0%)	42 (7,0%)	598 (100%)
More than 40	707 (47,1%)	290 (19,3%)	267 (17,8%)	166 (11,1%)	72 (4,8%)	1502 (100%)
Total	948 (44,8%)	404 (19,1%)	394 (18,6%)	254 (12,0%)	114 (5,4%)	2114 (100%)

Regarding teacher age (see Table 3), teachers over 40 years old show less use of FC (15.9 %), while those between 25 and 40 years old apply it more (21 %).

Table 4
Use of the FC methodology based on the teacher's years of experience

Experience (years)	FC (Coded Variable) - Case counts (%)					Total
	1	2	3	4	5	
Between 1 and 5	194 (45,0%)	97 (22,5%)	79 (18,3%)	41 (9,5%)	20 (4,6%)	431 (100%)
Between 6 and 10	153 (41,0%)	67 (18,0%)	72 (19,3%)	60 (16,1%)	21 (5,6%)	373 (100%)
More than 10	601 (45,9%)	240 (18,3%)	243 (18,5%)	153 (11,7%)	73 (5,6%)	1310 (100%)
Total	948 (44,8%)	404 (19,1%)	394 (18,6%)	254 (12,0%)	114 (5,4%)	2114 (100%)

Based on the teacher's years of experience (see Table 4), the use of FC is higher in teachers with 6 to 10 years of experience (sum of values 4 and 5 at 21.7 %) compared to teachers with 1 to 5 years of experience (14.1 %) and those with more than 10 years (17.3 %).

Table 5
Use of the FC methodology based on teacher's pedagogical training

Pedagogical training	FC (Coded Variable) - Case counts (%)					Total
	1	2	3	4	5	
Teacher Training Certificate (former CAP in Spain)	668 (45,3%	278 (18,9%)	281 (19,1%)	175 (11,9%)	72 (4,9%)	1474 (100%)
Master in Teacher Training	201 (40,9%)	102 (20,8%)	94 (19,1%)	62 (12,6%)	32 (6,5%)	491(100%)
None	26 (63,4%)	5 (12,2%)	3 (7,3%)	4 (9,8%)	3 (7,3%)	41 (100%)
Other	53 (49,1%)	19 (17,6%)	16 (14,8%)	13 (12,0%)	7 (6,5%)	108 (100%)
Total	948 (44,8%)	404 (19,1%)	394 (18,6%)	254 (12,0%)	114 5,4%)	2114 (100%)

After analyzing teacher training and its relationship with the FC methodology (see Table 5), it is observed that the percentage of FC use is similar between teachers with CAP pedagogical training (sum of values 4 and 5 at 16.8%) and those with a Master's in Secondary Education Teacher Training (19.1%), although it is slightly higher in the latter case.

Table 6
Use of the FC methodology according to the organization of classroom spaces

Type of classroom spaces	FC (Coded Variable) - Case counts (%)					Total
	1	2	3	4	5	
Open Classroom	19 (30,2%)	15 (23,8%)	19 (30,2%)	5 (7,9%)	5 (7,9%)	63 (100%)
Variable Structure Classroom	55 (26,8%)	25 (12,2%)	54 (26,3%)	46 (22,4%)	25 (12,2%)	205 (100%)
Subject-Specific Classroom	67 (42,1%)	28 (17,6%)	27 (17,0%)	28 (17,6%)	9 (5,7%)	159 (100%)
Classical rows layout	800 (48,2%)	325 (19,6%)	291 (17,5%)	170 (10,2%)	75 (4,5%)	1661 (100%)
Other	7 (26,9%)	11 (42,3%)	3 (11,5%)	5 (19,2%)	0 (0,0%)	26 (100%)
Total	948 (44,8%)	404 (19,1%)	394 (18,6%)	254 (12,0%)	114 (5,4%)	2114 (100%)

Regarding the physical teaching space (see Table 6), the use of FC is higher in classrooms with variable structure (34.6%), whereas in traditional classrooms with classical rows layout, the usage rate is approximately 15%.

Table 7

Evolution of the usage percentage of FC per classroom sessions over the semesters

SEMESTER	FC (Coded Variable)					Total
	1	2	3	4	5	
1S_20_21	77 (43,5%)	30 (16,9%)	33 (18,6%)	22 (12,4%)	15 (8,5%)	177
2S_20_21	166 (42,9%)	59 (15,2%)	77 (19,9%)	58(15,0%)	27(7,0%)	387
1S_21_22	158 (38,7%)	97 (23,8%)	81 (19,9%)	46 (11,3%)	26 (6,4%)	408 (100%)
2S_21_22	199 (44,4%)	88 (19,6%)	85 (19,0%)	57 (12,7%)	19 (4,2%)	448 (100%)
1S_22_23	185 (58,5%)	53 (16,8%)	36 (11,4%)	28 (8,9%)	14 (4,4%)	316 (100%)
2S_22_23	163 (43,1%)	77 (20,4%)	82 (21,7%)	43 (11,4%)	13 (3,4%)	378 (100%)
Total	948 (44,8%)	404 (19,1%)	394 (18,6%)	254(12,0%)	114 (5,4%)	2114 (100%)

Finally, according to the analyses of progress over time by Semesters (see Table 7), it is observed that the sum of values 4 and 5 over the semesters remains without significant variations, except in the first semester of the 2022/23 academic year, where a noticeable decrease in the use of FC is observed.

This data collected indicates that, although the use of the FC methodology varies more significantly depending on the teaching specialty, type of center, characteristics of the teachers, and physical teaching space. In general, its implementation is still limited compared to traditional methodologies since the majority of implementation levels are located in the coded values 1 and 2.

Statistically Significant Differences in the Implementation of FC According to Educational Variables

To analyze statistical differences between different groups defined by specific variables in relation to the use of FC, the Kruskal-Wallis test was employed. This statistical technique is used to determine if there are significant differences between three or more independent groups, without assuming a normal distribution of the data. For example, if we investigate the use of the FC methodology by type of institution, the groups would be: "public institution," "private institution," and "subsidized institution." In this scenario, each category represents a distinct group that we analyze to determine if there are significant differences when compared to the other two groups.

After applying the Kruskal-Wallis test to the variables in question, results have been obtained that allow us to perform hypothesis testing, comparing the data associated with each group. According to the findings, it has been determined that there are statistically significant differences in the use of FC in relation to the following variables: type of educational center (p-value: 0.041), area of knowledge (p-value $<$ 0.001), teacher's age (p-value: 0.004), type of physical space (p-value $<$ 0.001), and academic semester (p-value: 0.004). This indicates that the use of the FC methodology varies significantly depending on these variables. Moreover, a more detailed analysis of the results of the Kruskal-Wallis test will be presented in the Hypothesis Testing section.

Likewise, we employ the Mann-Whitney U test to examine variations in the application of FC. This test serves as a post-hoc analysis following the Kruskal-Wallis test, aiming to pinpoint the specific pairs of specialties among which significant differences exist in the utilization of FC. In the results, we identify two groups, labeled Sample 1 and Sample 2, representing different categories within the variables.

Table 8
Use of FC with respect to the specialty of knowledge

		Sample 2						
		Mathematics	Spanish Language and Literature	Biology and Geology	English Language	Geography and History	Physical Education	Prof. Training
Sample 1	Mathematics							
	Spanish Language and Literature	0,138						
	Biology and Geology	0,077	0,9					
	English Language	<,001	<,001	<,001				
	Geography and History	<,001	<,001	<,001	0,284			
	Physical Education	<,001	<,001	<,001	0,306	0,829		
	Prof. Training	<,001	<,001	<,001	0,047	0,139	0,211	

Note: P-values obtained after applying the Mann-Whitney U test. The significance level is < .050.

For the analysis of differences within each variable, we consider the data from the Mann-Whitney U tests presented in Tables 8-12 along with the descriptive values provided in Tables 1-7. Specifically, Table 8 shows the p-values resulting from comparing the use of FC among different specialties of knowledge. In this context, a significance level less than 0.050 indicates that the differences between groups are statistically significant. Therefore, we highlight that:

- Mathematics, Spanish Language & Literature, and Biology & Geology specialties show significantly lower use of FC compared to English Language, Physical Education, Geography and History, and Professional Oriented Training.
- The English Language specialty shows significantly lower use of FC compared to Professional Oriented Training.

These results indicate specific patterns in the adoption of the FC methodology among different educational specialties. In particular, they suggest limitations in the use of FC in traditionally more rigid areas, such as Mathematics and Spanish Language & Literature, compared to specialties that may offer more flexibility, such as English Language or Professional Oriented Training.

Table 9
Use of FC with respect to the type of institution

		Sample 2		
		Public	Subsidized	Private
Sample 1	Public			
	Subsidized	0,015		
	Private	0,078	0,945	

Note: P-values obtained after applying the Mann-Whitney U test. The significance level is < .050.

Following the previous reasoning, regarding the use of FC according to the type of institution (see Table 9), a lower usage is found in public centers, having shown statistically significant results, compared to subsidized centers (p-value: 0.015).

Table 10
Use of FC with respect to the teachers' ages

		Sample 2		
		Less than 25 years	Between 25 and 40 years	More than 40 years
Sample 1	Less than 25 years			
	Between 25 and 40 years	0,566		
	More than 40 years	0,21	<,001	

Note: P-values obtained after applying the Mann-Whitney U test. The significance level is < .050.

Regarding the use of FC, we conclude that there is lower usage among teachers over 40 years old compared to teachers aged between 25 and 40 years old (p-value <0.001).

Table 11
Use of FC with respect to the organization of classroom spaces

		Sample 2				
		Classical rows layout	Subject-Specific Classroom	Other	Open Classroom	Variable Structure Classroom
Sample 1	Classical rows layout					
	Subject-Specific Classroom	0,033				
	Other	0,208	0,734			
	Open Classroom	0,012	0,327	0,751		
	Variable Structure Classroom	<,001	<,001	0,107	0,07	

Note: P-values obtained after applying the Mann-Whitney U test. The significance level is < .050.

The results of the statistical tests indicate significant differences in the use of the FC methodology depending on the type of classroom space (see Table 11). Specifically, significant differences were found between:

- The use of FC in classical rows layout classrooms is lower compared to the organization in subject-specific classrooms, open classrooms, and classrooms with variable structure.
- The use of FC is higher in classrooms with variable structures compared to classical rows layout classrooms and subject-specific classrooms.

These findings suggest that the physical environment in which teaching is delivered significantly influences the implementation of the FC methodology.

Table 12

Use of FC with respect to the academic semester

		Sample 2					
		1S_20-21	2S_20-21	1S_21-22	2S_21-22	1S_22-23	2S_22-23
Sample 1	1S_20-21						
	2S_20-21	0,789					
	1S_21-22	0,852	0,916				
	2S_21-22	0,422	0,168	0,198			
	1S_22-23	<0,001	<0,001	<0,001	<0,001		
	2S_22-23	0,463	0,208	0,242	0,948	<0,001	

Note: P-values obtained after applying the Mann-Whitney U test. The significance level is < .050.

Similarly, significant differences are observed in the use of FC during the first semester of the 2022-23 academic year compared to the rest of the observed semesters (see Table 12).

HYPOTHESIS TESTING

After applying statistical tests to test hypotheses, the results obtained allow us to make significant comparisons between the data associated with each hypothesis (H1-H7):

H1. Type of educational institution and use of FC: The Kruskal-Wallis test revealed that the type of institution (public, private, or subsidized) is a statistically significant factor in the frequency of FC use, with a significance value of 0,041. This leads us to reject the null hypothesis, suggesting that the type of institution influences how FC methodology is adopted.

H2. The specialty of knowledge in secondary education and adoption of FC: Using the Kruskal-Wallis test, it was found that the specialty of knowledge (biology-geology, physical education, geography-history, English language, Spanish language-literature, mathematics, and professional-oriented training) is a statistically significant factor in the adoption of FC, with a significance value less than 0,001. This indicates a need to reject the null hypothesis, showing that the specialty area significantly affects the implementation of FC.

H3. Years of teaching experience and use of FC: The significance found in the Kruskal-Wallis test was 0,608, which indicates that the number of years of teaching experience does not significantly affect the use of FC, retaining hence the null hypothesis.
H4. Type of pedagogical training of teachers and adoption of FC: With a significance value of 0,513 in the Kruskal-Wallis test, it is concluded that the type of pedagogical training received by teachers is not a determining factor in the adoption of FC, thus retaining the null hypothesis.
H5. Age of teachers and adoption of FC: The test yielded a significance value of 0,004, indicating that the age of teachers is indeed a statistically significant factor in the adoption of FC. This leads us to reject the null hypothesis, indicating that age does influence the implementation of this methodology.
H6. The spatial arrangement of classrooms and use of FC: The analysis using the Kruskal-Wallis test showed a significance value of less than 0,001, revealing that the spatial arrangement of classrooms is a statistically significant factor in the use of FC. Therefore, the null hypothesis is rejected, suggesting that the physical classroom environment influences the application of FC.
H7. Relationship between the academic semester and the use of FC: With a significance value of 0,004 in the Kruskal-Wallis test, it is determined that the use of FC is significantly related to the academic semester, leading us to reject the null hypothesis. This indicates that the timing (by semesters) within an academic year affects the implementation of FC.

These results provide information about the factors influencing the adoption and practical implementation of the FC methodology, highlighting the importance of the type of educational institution (public, private, or subsidized), the area of knowledge, the age of teachers, and the spatial arrangement of classrooms, while years of experience and the type of pedagogical training of teachers were not identified as significant determining factors.

DISCUSSION AND CONCLUSIONS

Discussion

The results of this research on the use of the FC methodology concerning the type of educational institution show statistical differences between subsidized centers compared to public ones, without finding these differences between private and subsidized centers. These data are consistent with other studies that have also analyzed the use of this methodology based on the type of institution (Pozo et al., 2021). Among the reasons, the lack of technical-pedagogical resources and the teachers' lack of knowledge are identified as the main contributors to not using FC in classrooms. In this context, studies by Tucker (2012) have revealed a strong association between the utilization of this methodology and the resource availability within educational establishments. They noted that public institutions typically possess fewer technological resources in comparison to private ones (López-Aguado, 2020), and their students often have limited access to electronic and virtual tools as well as less familial support, resulting in lower cultural and human capital (Cabrera, 2020). Therefore, it is plausible to suggest that the observed discrepancy in usage may stem from underlying social and economic factors.

Another factor that, in line with our analyses, influences the application of FC in classrooms is the age of the teacher, where differences have been found among professionals over 40 years old compared to other younger age groups. This finding is consistent with other studies such as that of Vega et al. (2021), where age has been identified as a decisive factor in determining the digital competence of teachers across all its dimensions, with higher competencies found in the age groups between 31 and 40 years old. This fact, combined with the relationship between the degree of use of active methodologies and the level of teachers' digital competence (López et al., 2019; Hao & Lee, 2016), as defined by Andía-Celaya et al. (2020) as "highly improvable," could explain the lack of implementation of the FC model in classrooms by teacher groups over 40 years old. In this sense, teachers must be able to integrate new technologies into pedagogical models, even if they have very superficial knowledge about their use (Mollo-Torrico et al., 2023). Continuous training must play an essential role in ensuring the ongoing development of educational professionals (Torres & Álvarez, 2019) who facilitate the integration of active methodologies in the classroom.

It is worth noting that teaching experience has not proven to be a decisive factor, which might seem contradictory but aligns with Tello and Cascales (2015). The influx of mid-career professionals into teaching in recent years could explain this, as experience does not always correlate with age uniformly. However, attributing this difference solely to that factor would be speculative, warranting further research for clarification.

On the other hand, after analyzing the results concerning the semester variable, it is worth noting that the data appear to be fairly stable over time, with no significant differences found. The only exception is in the first semester of 2022-23, where a lower usage of FC is detected. It is possible that the initial effort to adapt to the new Spanish curricular legislation in secondary education (LOMLOE) could be behind this decline, but this hypothesis cannot be confirmed based on the data collected in this study.

Our study examines the use of FC after the pandemic, which began in early 2020. The shifts in educational paradigm during the lockdown situation have been well-documented in educational research, detecting changes in the utilization and management of resources (López et al., 2021), the onset of unforeseen virtual education (Estévez-Méndez & Moraleda, 2022), and an increase in emotional strain due to higher teaching workload and consequently increased stress during this period (Bravo-Villa et al., 2022). However, adaptations in the use of employed methodologies and the discovery of new available possibilities (Gómez-Hurtado et al., 2020; Purizaca-Gallo & Jolay-Benites, 2022) forced all teachers to face a technological challenge for which they were not prepared (Bonilla, 2020), but which allowed the creation of an alternative learning system particularly linked to student self-management and self-regulation (Muñoz & Lluch, 2020). In this sense, the stability detected in the use of FC can be interpreted as a sign of consolidation of this methodology in the educational institutions that continued to use it after returning to face-to-face instruction, demonstrating the partial consolidation of the learning made during the lockdown period.

It is also worth noting the significance of the specialty of knowledge when implementing the FC methodology, with two distinct groups observed: mathematics, Spanish language and literature, and biology and geology showing lower usage compared to physical education, geography, and history, English language, or professionally oriented training with higher usage. The reasons for this difference cannot be speculated on in this study, but further investigation into this topic is necessary to explore potential epistemological or academic social prestige reasons that may shed light on this disparity.

We have uncovered significant findings concerning the classification of classroom spaces and the use of FC methodology. Nonetheless, similar to the examination of the specialty of knowledge variable, it is prudent to approach these findings with caution due to the absence of supporting evidence in the scientific literature to corroborate the results obtained in this study.

Conclusions

In line with the findings presented here and in accordance with the analyzed scientific evidence, it can be affirmed that the FC methodology is applied unevenly depending on the age of the teacher, with its use predominantly among age groups under 40. Concerning the type of educational institution, a higher usage is observed in private and subsidized schools, which seems to stem from differences in training and available resources. The post-pandemic usage has remained fairly constant across different semesters analyzed, although there are fluctuations in its sporadic use in classrooms, the reasons for which are not clear but may be due to circumstantial factors. The variables of specialty of knowledge and classroom spatial typology have also shown significance, although further research is needed to confirm these differences and investigate their causes. It should also be noted that variables such as years of experience or pedagogical training of the teacher do not present significant differences when adopting the FC methodology.

The results obtained in this study will enable the educational community to understand the importance of key factors such as ongoing training associated with the age of the teacher, the development of digital competencies, or the relevance of having the necessary resources to implement the FC methodology in classrooms.

Limitations and Future Directions

One of the primary limitations of our study is the temporal scope of the sample used. We couldn't compare the results obtained with pre-pandemic data or reliable data on FC usage during the pandemic. Longitudinal studies over time are needed to identify potential trend changes.

Looking ahead, it is imperative to consider several directions in which research could be expanded to enrich and validate our conclusions. A promising line of inquiry would be to further explore those variables that have proven to be significant but lack comparative studies in the scientific literature. An example of this could be the detailed study of variations found in different specialties of knowledge or the examination of the impact of different types of classroom spaces. Additionally, the incorporation of additional variables, such as the gender of participants or a broader and more representative geographical distribution of the sample, could provide a deeper understanding of the use and peculiarities of the FC methodology analyzed in this study.

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Youtube and Instagram in higher education: media competencies of university teachers

Youtube e Instagram en educación superior: competencias mediáticas del docente universitario

Lucy Andrade-Vargas - *Universidad Técnica Particular de Loja, UTPL (Ecuador)*
Rigliana Portugal - *Universidad Mayor San Andrés, UMSA (Bolivia)*
Yamile Sandoval-Romero - *Institución Universitaria Antonio José Camacho, UNIAJC (Colombia)*
Cristhian Labanda-Jumbo - *Universidad Técnica Particular de Loja, UTPL (Ecuador)*

ABSTRACT

Accelerated access to the Internet, technologies and social networks contribute to the development of new educational contexts with significant transformations in teaching and learning. Broadening the conversation about these new scenarios is essential to understand the use of social networks and Edu Communication as a trend for the future. This study aims to identify and integrate the dimensions of media competencies in domains: skills, attitudes, and knowledge that professors should have to manage the teaching-learning process on YouTube and Instagram social networks. It employs an exploratory quantitative design, developed between 2021 and 2022, with a sample of 152 professors. Through an instrument validated for students and professors in Latin America, it analyzes the media competencies of: Language, Technology, Interaction Processes, Production and Dissemination Processes, Ideology and Values, and Aesthetics. The instrument is composed of 29 questions that establish domains: skills, attitudes and knowledge required by the professor to manage the teaching-learning process in networks such as YouTube and Instagram. As a result, it is obtained that there are no significant differences in the domains of knowledge, skills, and attitudes, i.e. university professors show a similar level of media competence on YouTube and Instagram. Teaching experience and age influence the development of media competence, with a greater integration of technological tools by professors with more experience, while younger professors show a greater disposition towards innovative media approaches such as the use of YouTube and Instagram.

Keywords: education; university professor; media competence; digital platforms; YouTube; Instagram.

RESUMEN

El acceso acelerado a Internet, las tecnologías y las redes sociales contribuyen al desarrollo de nuevos contextos educativos con transformaciones significativas en la enseñanza-aprendizaje. Ampliar la conversación sobre estos nuevos escenarios es indispensable para entender el uso de las redes sociales y la educomunicación como tendencia para el futuro. El presente estudio tiene como objetivo identificar e integrar la dimensión de la competencia mediática en dominios: habilidades, actitudes y conocimientos que debe tener el docente para gestionar el proceso de enseñanza-aprendizaje en las redes sociales de YouTube e Instagram. Emplea un diseño cuantitativo exploratorio, desarrollado entre 2021 y 2022, con una muestra de 152 profesores. A través de un instrumento validado para estudiantes y docentes de Latinoamérica, se analiza las competencias mediáticas de: Lenguaje, Tecnología, Procesos de interacción, Procesos de producción y difusión, Ideología y valores, y Estética. El instrumento se compone de 29 preguntas que establecen dominios: habilidades, actitudes y conocimientos que requiere el docente para gestionar el proceso de enseñanza-aprendizaje en redes como YouTube e Instagram. Como resultado se obtiene que no existen diferencias significativas en los dominios de conocimientos, habilidades y actitudes, es decir los profesores universitarios muestran un nivel similar en competencia mediática en YouTube e Instagram. La experiencia docente y la edad influyen en el desarrollo de la competencia mediática, con una mayor integración de herramientas tecnológicas por parte de profesores con más trayectoria, mientras que los profesores más jóvenes muestran una mayor disposición hacia enfoques mediáticos innovadores como el uso de YouTube e Instagram.

Palabras clave: educación; profesor universitario; competencia mediática; plataformas digitales; YouTube; Instagram.

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INTRODUCTION

The emergence of the Internet and technological development has transformed the creation and distribution of knowledge (Andrade-Vargas et al., 2021; Gutierrez-Martín, 2022), by changing teaching and learning contexts in recent years. The influence of virtual learning environments in education has increased dramatically due to the Sars-Cov2 pandemic, to the point of demanding adaptations aimed at creating hybrid and online educational contexts in a post-COVID world (Bashir, et al., 2021). This trend suggests challenges for the teaching community that must adapt to these new contexts and new teaching and learning tools, so that education walks hand in hand with technology and forms of communication such as social networks.

From this point of view, its use in education generates new opportunities for the development of content and resources that can be used synchronously and asynchronously, as well as the possibility of immediate and effective communication to increase participation in the teaching and learning processes; however, all these activities require that both professors and students have the necessary skills for their management (Chib et al., 2019).

Social networks allow the incorporation of knowledge, experiences, information, and communication technologies to improve the teaching and learning process, so the development of knowledge, skills and attitudes that allow optimal work with this type of tool is privileged. Likewise, these online learning communities are increasingly popular, for collaborative dialogue and knowledge creation (Xing & Du, 2023), establishing a dialogic and direct interaction that contributes to the learning of both professors and students (Ruay Garcés & Campos Palacios, 2019).

As the Global Digital Report (2024) points out, the number of YouTube users has reached 2.491 million, while Instagram has reached 2 billion. On YouTube, young people spread ideas and beliefs, based on their relationship activities, common interests, and goals (Vizcaíno-Verdú et al., 2019), while on Instagram young people seek to connect, discover novelties, show their lives, discover new "role models", among others.

With the growing use of both networks worldwide, the education sector is moving towards a future in which the incorporation of these tools will be part of teacher training curricula to have greater interaction and communication in the teaching and learning processes (Sánchez, 2018), given that both involve the active participation of students.

This study proposes a set of teaching media competencies for the use of the social networks YouTube and Instagram for teaching and learning with students taking advantage of the particularities that these social websites have (Sánchez, 2018).

University professors in the media ecosystem

The processes that take place in the educational space do not always advance at the same pace as technological changes and, in fact, higher education institutions should be at the forefront and adopt the use of technology and alternative forms of education such as social networks at the same pace as other types of organizations (Aldahdouh et al., 2020). In Latin American countries, the path for the incorporation of technologies in educational scenarios is marked by an instrumental approach and only until very recently managed in a comprehensive manner. Longitudinal studies demonstrate their effectiveness in education, with the incorporation of mobile devices (Mehrolia et al., 2021) or technologies inside and outside the classroom (Jahnke & Liebscher, 2020) presenting evidence of their contribution.

In the current media ecosystem, social networks, although not educational in nature, become tools to support teaching. As producers of educational content or as tools for content creation in the learning process (Hamadi et al., 2021), they allow professors to explore new ways of approaching the digital world.

The massification and democratization of social networks (Andrade-Vargas et al., 2021) consolidate a drastic change in the traditional roles of "creator" and "consumer". Currently, both teachers and students have become authors, co-authors and prosumers of media and educational products (Scolari, 2016). As prosumers, professors design strategies in the classroom, preferably using YouTube to create their videos or to propose creations to their students (del Valle-Ramón et al., 2020). Instagram stands out with multiple educational functionalities, although without reaching its full potential (Carpenter et al., 2020).

This reality reinforces the need to intervene with training spaces in media competencies that strengthen the critical capacity for responsible citizenship (Alcolea-Díaz et al., 2020) in the use of these tools.

Social networks, Youtube and Instagram, and University professors

Social networks are currently becoming the predominant form of communication worldwide, with more than 5 billion users worldwide (Global Digital Report, 2024). The widespread interest in the use of these for educational purposes in higher education is the natural result of their growing popularity in different digital environments within the Internet (Gaftandzhieva & Doneva, 2021) considering that at this level students coexist in a virtual environment where they manage their learning autonomously (Vico-Bosch & Rebollo-Catalán, 2018).

The use of social networks in education implies that the professor has skills to work with the different applications and tools, in addition to seeking empowerment at the subject level (Chib et al., 2019). It has also been observed that these platforms allow knowledge sharing among professors and colleagues (Owusu et al., 2019), considering these spaces as scenarios to forge skills and attitudes oriented to the production, management, and analysis of content (Rios Hernández et al., 2022). These are some of the reasons why universities should provide networking spaces within their classroom work to promote social learning.

Instagram is prominently favored among young individuals as a primary tool for sharing information, documenting their lives, acquiring knowledge, and exploring emerging trends (Hussain et al., 2024; Owusu et al., 2019). Among the multiple options used by this network, images, photos, and videos stand out, the same that promote positive attitudes and values within the classroom, as well as greater motivation towards participation. This social network allows sharing resources for students to interact (Mansor & Rahim, 2017), hence professors put their interest in the use of this platform in the classroom to achieve interaction and motivation of students among peers (Mansor & Rahim, 2017).

On the other hand, the use of YouTube in education allows improving the experience in terms of learning, since, many professors seek the implementation of it within their classrooms for the development of new skills, from the systematization of the information of the contents that are addressed within the subjects or courses (Ruay & Campos, 2019), being an educational communication tool that supports the teaching-learning process (Posligua-Anchundia & Zambrano, 2020).

The use of YouTube and Instagram and the constant advance of technology have allowed the generation of new spaces for interaction and content consumption (Arellano et al., 2020), especially in higher education institutions. From this situation the importance for professors to develop innovative and necessary competences for a different way of working in the management and design of didactic resources for learning how to use social networks is derived. This panorama becomes more complex if we consider the world of algorithms that are growing at a rapid rate in the context of people's everyday lives.

Media competence in university professors: Knowledge, skills, and attitudes

In the mid-twentieth century, the term competency found its antecedent in the globalization of the economy, which sought to ensure the profitability and competitiveness of production centers, giving priority to the workforce in companies. Subsequently, education opened its doors to the development of competencies, based on an approach aimed at strengthening the skills required by the market.

Regarding the development of media competencies, the process has been nurtured from the conceptual basis to practice. The term configures a multidimensional concept (Fedorov & Levitskaya, 2015) in which, a competency is recognized as that knowledge, skills, and attitudes that a person should have, and which translate into the relationship between "knowing", "knowing how to do" and "knowing how to be" (García Ruiz et al., 2018). It is a "holistic and contextualized vision of learning" (Delgado-Ponce & Pérez-Rodríguez, 2018, p. 19), where "knowledge, skills and attitudes, in an interrelated and complex manner, are put into practice to intervene effectively in concrete situations" (Delgado-Ponce & Pérez-Rodríguez, 2018, p. 14).

Given the globalized media context (Álvarez-Arregui et al., 2017), it is important to work on continuous training and the development of media competence to be prosumers with critical thinking at the level of reception and production of messages. It is about going beyond a "techno-solutionist" approach to move towards the development of personal autonomy (Mateus et al., 2019). In this framework, the Alliance of Civilizations reaffirms that the development of critical thinking is fundamental in the face of mass media especially considering that "the production of media messages has grown due to the participation enabled by Web 2.0" (Delgado-Ponce & Pérez-Rodríguez, 2018, p. 18). Developing critical and autonomous thinking is a process that refers to the necessary deepening in education, from the strengthening of media competence that responds to the digital, audiovisual, and intercommunicated scenario, where the role of the professor from the management, facilitation and promotion of media and digital competence is unavoidable (Salcines-Talledo et al., 2017).

At the research level, it is essential to work with theoretical and methodological support. Under these criteria, two researchers who have contributed to methodologically operationalize the concept of media competence are Ferrés and Piscitelli (2012) for whom media competence comprises the mastery of knowledge, skills and attitudes linked to six basic dimensions, through which the respective indicators are created. These proposed dimensions are related to both analysis (how people receive and interact with messages) and expression (how people produce messages). The dimensions are Language, Technology, Interaction Processes, Production and Dissemination Processes, Ideology and Values, and Aesthetics.

Therefore, this study aims to identify and integrate the dimensions of media competencies in skills, attitudes, and knowledge that professors should have to manage the teaching-learning process in the YouTube and Instagram social network.

METHODOLOGY

This study followed a quantitative design with an exploratory scope and was carried out over one year, between 2021 and 2022. This design encompasses a set of sequentially organized processes and is appropriate when one wants to estimate the magnitudes or occurrence of phenomena. The choice of an exploratory scope is justified since the study examines a new or little-studied phenomenon or research problem, about which there are many doubts, and which has not been addressed before (Hernández-Sampieri & Mendoza Torres, 2018).

Type of study

For this research, a non-experimental design of transversal type is used, collecting data at a single moment and without the deliberate manipulation of variables, to observe the phenomena in their natural environment and analyze them (Hernández-Sampieri & Mendoza Torres, 2018). By not manipulating the variables, possible distortions introduced by the intervention of the researcher are avoided, likewise, this design empowers the examination of the relationships between variables in an observational manner, providing key points on the interactions between the elements of the phenomenon in question.

Participants

The selected sample consisted of 152 university professors who participated on a voluntary basis and at the moment of data collection worked in higher education institutions in Argentina (22.4 %), Bolivia (15.8 %), Colombia (36.8 %) and Ecuador (25.0 %). Due to the nature of self-selection sampling, the sample reveals significant diversity in terms of geographic origin, with many participants from Colombia and Ecuador. In terms of gender, there is an even distribution between men and women. The age of the respondents varies widely, although the majority are in the range of 36 to 55 years old.

Regarding teaching experience, there is a relatively even distribution among the different ranges of experience, with a significant percentage of participants with more than 10 years of experience. In terms of educational level, the majority have at least a master's degree, reflecting a highly qualified and diverse educational group. As shown in Table 1, the sample has varied profiles in terms of gender, age, years of experience and educational level. This not only provides a more complete representation of the target population, but the analysis can better capture the possible influences of these demographic variables on the results, allowing for a deeper and more accurate understanding of the phenomenon studied.

Table 1
Demographic profile of the sample

Criterion	Description	Frequency	Percentage
Country of origin	Argentina	34	22,4 %
	Bolivia	24	15,8 %
	Colombia	56	36,8 %
	Ecuador	38	25,0 %
Sex	Male	80	52,6 %
	Female	72	47,4 %
Age	21 to 25 years old	3	2,0 %
	26 to 30 years old	4	2,6 %
	31 to 35 years old	18	11,8 %
	36 to 40 years old	38	25,0 %
	41 to 45 years old	16	10,5 %
	46 to 50 years old	22	14,5 %
	51 to 55 years old	26	17,1 %
	56 to 60 years old	22	14,5 %
	Over 60 years old	3	2,0 %
Teaching experience	From 1 to 5 years old	28	18,4 %
	From 6 to 10 years old	27	17,8 %
	From 11 to 15 years old	39	25,7 %
	From 16 to 20 years old	28	18,4 %
	From 21 to 25 years old	15	9,9 %
	From 26 to 30 years old	6	3,9 %
	More than 30 years old	9	5,9 %
Education level	Undergraduate / Degree	23	15,1 %
	Master's degree / Specialization	89	58,6 %
	Doctorate (PhD)	33	21,7 %
	Postdoctoral	7	4,6 %
	Other	0	0,0 %

To ensure the ethical integrity of the study, all participants were informed of its aims and expressed their explicit consent to take part in it and were encouraged to raise any questions or concerns. They will receive the results once the study is concluded, which guarantees transparency, respect for autonomy and compliance with the ethical standards of the research.

Instrument

For this research, the instrument used to measure media competencies was adopted from Ferrés and Piscitelli (2012) and validated by Ríos-Hernández et al. (2020) for implementation among students and professors in Latin American contexts, including cases from Colombia, Ecuador, Bolivia, and Argentina. The media competencies analyzed are Language, Technology, Interaction Processes, Production and Dissemination Processes, Ideology and Values, and Aesthetics. The instrument consisted of 29 closed-ended questions of nominal and ordinal level (Table 2).

Table 2

Questions, dimensions, mastery, and reliability - media competence

Questions	Dimension	Domain	Cronbach Alpha
- Elements that interact on YouTube and Instagram. - Time you spend on daily consumption of YouTube and Instagram - Purpose, use of video applications and design - Development of audiovisual production - Use of YouTube and Instagram video - Use of photos and images on YouTube and Instagram - Frequency of use of YouTube and Instagram for classes. - YouTube and Instagram helped you to strengthen your classes.	Interaction processes	Knowledge	,735
- Language (vocabulary) transmitted on YouTube and Instagram. - Use of hashtags (#) or keywords - Terms you use to interact on YouTube	Language	Skills	,791
- YouTube and Instagram resources that you use frequently in the classroom. - Handling of the social networks YouTube and Instagram - Social networks or platforms that you use the most for your studies - Devices to access YouTube and Instagram - Use of YouTube and Instagram - Resources for creating academic content on YouTube and Instagram - Handling of video and design applications to create content on YouTube and Instagram	Production and dissemination processes	Skills	,791
- Content creation (photos, audios, videos, images, etc., on YouTube and Instagram). - The accounts you follow on YouTube and Instagram. - Criteria for selecting the content you publish on YouTube and Instagram.	Technology	Skills	,791
- People or groups you follow on YouTube and Instagram - The accounts you follow on YouTube and Instagram - Ideological and value motivations to convey the content you creates on YouTube and Instagram.	Ideology and values	Attitudes	,791
- Aspects to value in a photo to be published on YouTube and Instagram. - Elements of images to be published on YouTube and Instagram - Aspects of photographs	Aesthetics	Attitudes	,791

Data analysis

The data collected were analyzed using descriptive and inferential statistics with the help of the SPSS program (V.22.0). The domains: skills, knowledge and attitudes were elaborated from the raw scores (arithmetic sum of the items corresponding to the competencies of each dimension identified) and converted into percentage ratios.

The Kolmogorov Smirnov test was used to analyze the normality of the domains: knowledge, skills, and attitudes, as explained in Table 3, the results of which showed that the data did not follow a normal distribution. These were used to test hypotheses and determine whether there was a significant difference between the groups means using the Kruskal-Wallis test.

Table 3

Kolmogorov-Smirnov test for the sample

		Knowledge	Skills	Attitudes
N		152	152	152
Normal parameters	Mean	40,486	40,004	58,778
	Standard deviation	18,7444	14,4061	21,1761
Minimum		6,7	14,4	6,8
Maximum		91,7	76,6	97,7
Maximum extreme differences	Absolute	,079	,074	,067
	Positive	,079	,074	,065
	Negative	-,054	-,043	-,067
Test statistic		,079	,074	,067
Asymptotic sig. (bilateral)		0,021	0,041	0,093

RESULTS

Table 4 presents the results of the domains of media competence: knowledge, skills, and attitudes, according to the demographic profile (country of origin, age, gender, teaching experience and level of education) of university professors from Argentina, Bolivia, Colombia, and Ecuador. It also includes the results of the Kruskal-Wallis (KW) test for each domain, establishing whether there are significant differences between the groups defined by demographic variables.

It is observed that there are no significant differences in the domains of knowledge, skills, and attitudes among the countries ($p > 0.05$), according to the Kruskal-Wallis (KW) test, i.e., these domains are developed to the same extent in the four countries analyzed. In turn, age is a factor influencing the three domains, given that significant differences are observed in all dimensions with respect to age ($p < 0.05$), indicating that the means of knowledge, skills and attitudes vary significantly among the different age groups, being higher in the younger segments.

Gender and level of education are not determining factors in the development of the three domains, since no significant differences are observed in relation to knowledge, skills and attitudes between men and women ($p > 0.05$), nor between the various levels of education ($p > 0.05$). However, teaching experience, as well as age, do make a difference, as they are significant in all domains ($p < 0.05$), suggesting that the length of teaching experience influences professors' media competencies.

Table 4

Domains of media competence: knowledge, skills, and attitudes

Criterion	Description	Knowledge			Skills			Attitudes		
		Mean	SD	KW	Mean	SD	KW	Mean	SD	KW
Country of origin	Argentina	41,9	20,1	0,255	41,9	13,6	0,095	61,9	22,0	0,139
	Bolivia	33,8	15,4		33,7	14,0		49,9	20,3	
	Colombia	41,3	19,9		40,4	14,8		59,0	20,9	
	Ecuador	42,2	17,4		41,8	14,2		61,3	20,7	
	Total	40,5	18,7		40,0	14,4		58,8	21,2	
Age	21 to 25 years old	55,0	32,5	0,000	54,7	17,3	0,000	68,2	16,4	0,002
	26 to 30 years old	48,8	31,5		48,7	15,3		71,0	26,9	
	31 to 35 years old	54,0	17,5		50,5	14,7		73,0	18,1	
	36 to 40 years old	45,9	14,6		44,0	10,5		64,7	18,2	
	41 to 45 years old	38,9	16,5		34,8	12,5		49,7	20,7	
	46 to 50 years old	42,3	16,9		40,1	16,2		59,5	20,3	
	51 to 55 years old	33,0	16,7		34,7	14,5		50,6	21,5	
	56 to 60 years old	27,0	16,9		32,5	11,0		51,1	21,4	
	Over 60 years old	24,4	7,9		28,2	11,6		42,5	5,3	
	Total	40,5	18,7		40,0	14,4		58,8	21,2	
Sex	Male	41,0	17,0	0,752	39,6	12,4	0,99	58,4	21,2	0,819
	Female	39,9	20,6		40,4	16,4		59,2	21,3	
	Total	40,5	18,7		40,0	14,4		58,8	21,2	
Teaching experience	From 1 to 5 years	48,6	20,8	0,006	46,5	14,5	0,015	70,5	16,0	0,013
	From 6 to 10 years	44,8	19,3		42,5	15,7		60,1	20,7	
	From 11 to 15 years	40,8	16,9		40,1	13,6		58,9	22,6	
	From 16 to 20 years	39,9	14,1		38,5	12,8		56,0	20,5	
	From 21 to 25 years	28,7	16,4		32,8	13,7		49,1	20,2	
	From 26 to 30 years	34,5	23,0		38,7	14,9		45,1	28,6	
	More than 30 years	26,3	17,7		29,6	10,4		51,8	15,7	
	Total	40,5	18,7		40,0	14,4		58,8	21,2	
Education level	Undergraduate / Degree / Career	49,8	16,7	0,09	43,3	13,5	0,587	67,9	18,4	0,128
	Master's degree / Specialization	38,8	18,5		39,0	14,1		58,3	19,7	
	Doctorate (PhD)	39,0	19,0		40,0	15,0		54,6	24,3	
	Postdoctoral	38,1	21,6		42,6	19,5		54,2	27,2	
	Total	40,5	18,7		40,0	14,4		58,8	21,2	

Note: KW: Kruskal-Wallis test for independent samples; SD: standard deviation

Knowledge

The results obtained suggest that the level of knowledge about media competence on YouTube and Instagram among university professors from Argentina, Bolivia, Colombia, and Ecuador is comparable, evidencing a certain similarity in the acquisition and understanding of concepts and theories related to the media in an educational context.

Both men and women, regardless of their educational level, have an equal level of knowledge, which defies gender stereotypes and shows that education, access to information and the use of social networks level out the differences in the development of knowledge in this area.

Skills

The uniformity presented with respect to professors´ skills suggests a generalized exposure to media, social networks and technologies that reflect the same trend within the region, as well as the domain of similar educational approaches. However, the fact that younger university professors are better equipped with media skills than professionals with more years in the teaching profession, responds to the fact that the first group grew up in a context with notorious digital influence and are more familiar with technologies, media and social networks, a situation that enhances their media skills and abilities on an almost permanent and continuous basis.

Although neither gender nor educational level can be considered determining factors, teaching experience is positioned as a significant variable that influences the development of media skills, supporting the argument that the time dedicated to teaching activities not only affects the pedagogical skills achieved, but also enriches those related to media competence in the use of the social networks YouTube and Instagram. In this sense, professors with more experience increase their opportunities to integrate media tools in their teaching practice, reflect on their application in the classroom and contribute to their mastery.

Attitudes

Attitudes developing media competence in YouTube and Instagram are similar among university professors in the four countries analyzed, which implies a generalizable trend in the perception and valuation of their importance in the teaching-learning process. However, and like the previous domain, it is the younger university professors who evidence a more favorable disposition towards media competence, with greater openness to the integration of innovative media approaches; it should be considered that these attitudes are currently perceived as essential for professional success in the current landscape.

The valuation and perception of the importance of media competencies in social networks such as YouTube and Instagram do not present an influence linked to gender or educational level, but again teaching experience is consolidated as a significant factor within media competencies, which promotes a greater valuation of their domains as an integral part of teaching and learning. Thus, prolonged exposure (years of work) to the demands and challenges of teaching leads to a higher valuation of media competencies in YouTube and Instagram as effective tools to facilitate the established teaching-learning process.

DISCUSSION AND CONCLUSIONS

This research describes the competencies that a university professor should have to teach and learn using YouTube and Instagram. The use of technology and these platforms for university teaching is a trend that will continue in a post Covid world, so it is necessary to develop competencies to make these new educational phenomena effective, considering that the adoption of technology is usually modeled as a process with dynamic transitions between costs and benefits.

There are no significant differences between countries in the domains of knowledge, skills and attitudes in media competence on YouTube and Instagram, which suggests that, despite variations in the educational and cultural systems of each country, university professors develop media competence at a similar level, a situation that is relevant in a globalized context where technology and media such as social platforms, have a cross-cutting impact on education. That being said, some authors (Marín et al., 2023) consider that cultural values infer the levels of media competence.

This raises questions about training and professional updating strategies, suggesting that it is necessary to implement specific programs that address the needs of older professors to ensure an equitable development of media competencies in all groups. Platforms such as YouTube and Instagram should be used to innovate student learning through the selection and integration of content and resources, offering favorable conditions for dialogue and collaborative learning.

Teaching experience and age emerge as a relevant factor in the development of YouTube and Instagram media competence, with a greater integration of technological tools by professors with more experience, while younger professors show a greater disposition towards innovative media approaches such as the use of social networks: YouTube and Instagram. This highlights the criterion of Tsankova et al. (2023), the importance of continuous training and professional learning throughout a professional teaching career to stay updated in a constantly evolving technological educational environment with key skills for living and working in the 21st century.

Looking to the future, it will be necessary to strengthen the critical attitude of the users of these networks, considering the presence of platforms that, from the educational point of view, as highlighted by Zuboff (2019), are increasingly personalized, according to the interests of the users. As suggested by Barrero-Fernández et al. (2023), at the educational level, the development of different types of collaborative networks is seen, which has led in recent years to generate links and different forms of collaboration.

The data collected contribute comprehensively to the understanding and development of professors´ media competence on YouTube and Instagram. By integrating innovative pedagogical strategies, the model emerges as a valuable resource to strengthen the educational presence in these digital spaces, allowing professors not only to effectively navigate technological tools, but also to enhance their educational and communicational impact. Faced with this reality, authors such as Sinan and Yener (2023), point out that the use of educational technologies reforms educational systems to train dynamic individuals who can meet the needs of society, as well as technology.

This study is a significant step towards the consolidation of a more skilled and versatile teaching community with respect to the current digital scenario, where media competence on YouTube and Instagram becomes part of effective teaching and meaningful interaction with students. The influence of teaching experience on the development of media competence in social networks highlights the importance of fostering spaces for the exchange of good practices and continuous training so that professors continue to update themselves in this area.

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In the future, it is necessary to propose longitudinal research that will allow a long-term evaluation of media competencies on YouTube and Instagram in professors to establish an analysis of trends, exploration of effects, consideration of technological-cultural changes and the needs for continuous training presented by the teaching community in higher education.

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Digital andragogy: the need to know and the role of experience in an online Master's degree

Andragogía digital: necesidad de saber y papel de la experiencia en un Máster universitario en línea

Iluminada Sánchez-Doménech - *Universidad Internacional de La Rioja, UNIR (Spain)*
Miguel Ángel Cabeza-Rodríguez - *Universidad Internacional de La Rioja, UNIR (Spain)*

ABSTRACT

The current high demand for online learning, the high drop-out rates, and the heterogeneity of students taking online master's degrees call for attention to be paid to the different profiles and their different ways of learning. Andragogy provides a theoretical framework for understanding adult learning, although its principles need to be revisited from the perspective of online learning and through the lens of today's learners themselves. This study aims to understand learners' self-identification with the adult learning principles of Knowles' andragogy. Specifically, it focuses on two of the principles of this theory: the need to know (NK) and the role of experience (RE). A mixed method approach was employed: a descriptive and inferential quantitative analysis of a questionnaire was complemented by a qualitative analysis of interviews. A questionnaire was designed, validated, and completed by 245 postgraduate students, and the correct reliability of the instrument was analysed. In addition, 5 interviews were carried out with students on items of the questionnaire. The results show statistically significant differences in the RE according to previous work experience in education, but no differences are found in the preferences for the learning strategies analysed related to the NK and RE principles of andragogy according to gender, age, or work situation. In conclusion, the validity of the NK and RE andragogical principles for online learners in the 21st century is defended.

Keywords: adult learning theory; online education; higher education; andragogy, student profile; learning strategies.

RESUMEN

La alta demanda actual de formación en línea, las elevadas tasas de abandono y la heterogeneidad del alumnado que cursa másteres en esta modalidad, reclama poner atención en los distintos perfiles y sus diferentes formas de aprender. La andragogía provee un marco teórico para comprender el aprendizaje de las personas adultas, aunque es necesario revisitar sus principios desde la formación en línea y a través de la lente de los propios estudiantes actuales. El objetivo de este estudio es conocer la autoidentificación de los estudiantes con los principios del aprendizaje adulto de la andragogía de Knowles. En concreto, se centra en dos de los principios de esta teoría: la necesidad de saber (NS) y el papel de la experiencia (PE). Se empleó un método mixto: un análisis cuantitativo descriptivo e inferencial de un cuestionario se complementa con un análisis cualitativo de entrevistas. Se diseñó y validó un cuestionario que cumplimentaron 245 estudiantes, y se analizó la correcta fiabilidad del instrumento. Adicionalmente, se llevaron a cabo 5 entrevistas al alumnado sobre ítems del cuestionario. Los resultados muestran diferencias estadísticamente significativas en el PE en función de la experiencia laboral previa en educación, pero no se encuentran diferencias en las preferencias por las estrategias de aprendizaje analizadas relacionadas con los principios NS y PE de la andragogía en función del género ni la edad ni situación laboral. Como conclusión, se defiende la vigencia y validez, de los principios andragógicos NS y PE para el alumnado en línea del siglo XXI.

Palabras clave: teoría del aprendizaje adulto; enseñanza en línea; educación superior; andragogía, perfil estudiantil; estrategias de aprendizaje.

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INTRODUCTION

In the current context of distance higher education, characterized by the plurality of student profiles, the focus of academics has shifted from accessibility of training to pedagogical innovation (Lee, 2017), quality of training (Smidt et al., 2017), maximizing learning (Kleinke & Lin, 2020) and minimizing dropout (García Areito, 2019), which is 21.8% according to the Ministry of Universities of the Government of Spain (2023).

According to Ferreira and Mclean (2017), one of the main causes of high dropout is that instructional design does not consider how the diverse characteristics of adult learners who choose distance and online learning are distributed. Knowles (1980, 1990) is considered the father of *andragogy,* popularizing the term during the 1960s and 1970s to name adult education as opposed to pedagogy. Although his claim to construct a general theory to guide the practice of adult educators has been criticized for forgetting "the big three": class, gender, and ethnicity (St. Clair & Käpplinger, 2021), it remains for many educators a theoretical frame of reference.

Concerning gender, criticisms of Knowles' andragogy theory claim that women have specific characteristics that would affect their learning style and that is not reflected in the theory (Merrian, 2001). Online learners are predominantly female, employed, and older than traditional university students (Tainsh, 2016), so the online mode would be of particular relevance to test the validity of the theory's assumptions and its alleged gender bias.

According to Donavant (2009), it is true that andragogy is not a panacea for adult education practices, but its usefulness for a better understanding of adult learning should not be ignored. As Knowles (1980) foresaw, new information and communication technologies have made possible the creation of collaborative learning environments and interaction, both with a large amount of content, with the learning facilitator and among learners.

However, andragogy was developed for face-to-face instruction, so online learning must revisit it (Arghode et al., 2017; Blackley & Sheffield, 2015; Kennan et al., 2018) to develop a digital andragogy that responds to the learning needs of today's adult learners who choose online learning in the 21st century.

Numerous studies have analysed the impact on academic outcomes and student satisfaction of using andragogy in university teaching and continuing professional development (Akintolu & Letseka, 2021; Aljohani & Alajlan, 2021; Kamışlı & Özonur, 2017; Kleinke & Lin, 2020; Sato et al., 2017; Velardi et al., 2020; Youde, 2018; Watts, 2018). Kennan et al. (2018) explored different preferences for teaching performances as a function of social status and age within andragogy. However, a deficit of research has been identified in the Spanish context within the framework of adult education theory, or andragogy, on the practices of online learning that best suit the specific needs of learners, possible differences in terms of age and gender, as well as the use of andragogical principles (Rodrigo et al., 2024) as a reference for developing didactic strategies.

It is therefore considered relevant to explore a theory of adult learning in 21st-century digital environments that guides both the meaning of LMS (Learning Management Systems) design and teaching practices and research on the improvement and effectiveness of online student learning (Sun & Chen, 2016).

This research explores two of the principles that Knowles (1980, 1990) characterizes adult learning: the *need to know* (NK) and the *role of experience* (RE) as a basis for possible methodological strategies in the "Postgraduate Certificate in Education" (PGCE) at an online university and how these teaching preferences are distributed among learners according to age, gender, employment status and previous experience in the sector.

Online University Students: Traditional and Non-traditional Learners

A defining characteristic of online university education is the heterogeneity of its students in terms of age, life and professional experiences and interests. The characteristics of adult learners is one of the most researched topics in distance education, and has led to the classification of its students as traditional and non-traditional (Martin et al., 2020) with age as the most common classification criterion. However, it is prior knowledge and work experience that actually defines non-traditional students (Carreira & Lopes, 2019).

In the context of university education, traditional students are those who have continued their studies uninterruptedly until they reach postgraduate education. Therefore, they would be in the age range 24–26 years; while non-traditional students are those over 26 years of age who have returned to their studies after a more or less prolonged period of time away from the academic environment and who are usually employed (de Abreu, 2020; Deschacht & Goeman, 2015; Kleinke & Lin, 2020).

Some of the advantages that online and distance learning provides for adult learners is that they can enjoy greater time flexibility when juggling work, study, hobbies, and family responsibilities (de Abreu, 2020; Deschacht & Goeman, 2015), but time flexibility does not mean more time for learning, so it is important to understand the strategies that learners use to adapt to the online learning environment.

Non-traditional students tend to relate more to faculty members, value faculty more positively, and show greater behavioural and cognitive engagement (Lee, 2017; Vuori, 2019), while traditional students prioritize relationships with peers (de Abreu, 2020; Vuori, 2019). According to Lee (2017), today's students are customer service-oriented, resource-demanding and credential-oriented; these "consumer learners" tend to be less patient when they encounter drawbacks in their learning, and have higher demands for institutional services to match their needs on the basis that their education is an investment of time and money; non-traditional distance learners tend to be grateful for the educational opportunities provided, respectful of providers and compliant with established systems.

In general, highly educated students tend to express lower satisfaction with web-based distance education (Ke & Kwak, 2013). The main motivation for obtaining a PGCE for younger students is instrumental, to improve employment prospects (de Abreu, 2020; Liu & Morgan, 2018), while for older students, career reorientation or self-fulfilment would be more important (de Abreu, 2020; Carreira & Lopes, 2019). Soft skills, such as communication and time organization acquired through work experience, are more common characteristics for non-traditional students (Carreira & Lopes, 2019). In general, mature students want courses that are well-designed, so that they can improve their chances of successful completion (Sun & Chen, 2016).

Andragogy in the Practice of E-Learning: The Need to Know and the Role of Experience

Knowles (1980) described five principles that supposedly define adult learners and differentiate them from children and young learners:

1. Self-concept: As a person matures, the self-concept changes from a dependent personality to a self-directed person and therefore expects to be treated as such.
2. Role of experience: As a person matures, he or she accumulates a growing reservoir of experience as a resource for learning.
3. Willingness to learn: as a person matures, his or her willingness to learn becomes increasingly oriented toward real-life social role development tasks.
4. Learning orientation: as a person matures, his or her time perspective changes from a postponed application of knowledge to an immediate application and, consequently, his or her learning orientation changes from one that is subject centred to one that is oriented to real life or career problems.
5. Intrinsic motivation: as a person matures, the motivation to learn is internal, although it may coexist with some external motivators.

These principles were not intended to be universal, "but rather a continuum of assumptions to be tested in terms of suitability for particular learners in particular situations" (Knowles, 1980; p. 391). In the case of students enrolled in an online PGCE, it is assumed that they possess a range of qualities such as self-motivation, confidence, time management skills, financial resources, and technological competence necessary for success in an online environment (Lanford, 2020). Donavant (2009) points out another factor that is worth noting in the context of this research, which is that when adult education is compulsory, such as the PGCE qualification for teaching, it often leads to anger, lack of motivation, and a sense of disenfranchisement. In the specific case of the PGCE, the motivation factor is also affected by the fact that prospective teachers typically undervalue the psycho-pedagogical knowledge provided by the PGCE compared to their academic specialism and experience (Pontes et al., 2010).

Adult Learners' Need to Know

According to Knowles (1980), pedagogy assumes that the learner only needs to know that he/she must learn what the teacher teaches if he/she is to pass or be promoted, and not how he/she will apply what he/she learns in his/her life. In contrast, andragogy considers that the adult person needs to know why they need to learn something before they start learning, and how they can use it in their real life. Consequently, the learning facilitator must help the learner to be aware of the need to know what he or she intend to teach (Knowles, 1980). The perception of a high level of relevance in the learning environment is the most powerful determinant of satisfaction with online courses (Ke & Kwak, 2013).

Ferreira and Mclean (2017) note that adult online learners are characterized by a drive for immediate access to the benefits derived from their learning, and a desire to quickly apply these benefits to career advancement and other personal goals; they lack patience and need to be given reasons why the path to desired learning goals may be longer and more arduous than expected.

Therefore, instructional design must align learning objectives with the learner's real-world needs (Ferreira & Mclean, 2017). The “learning facilitator” (Knowles, 1980) must help the learner connect the course content to the work environment (McCauley et al., 2017). Given the profile of this learner, in terms of work and family situation, they need to plan their study engagement effectively (Sun & Chen, 2016), and select the resources they will use to optimize their learning, so it may be important at the beginning of the course to brief students on key information (Youde, 2018), as well as express clear expectations to adult learners to enable their planning (Schultz, 2012).

Adult learners do not want surprises, they want to know at the outset what is expected of them, and what they can expect from the teacher (Bailey & Card, 2009). Knowing the structure of the course at the outset is one of the factors that affect adult learners' satisfaction; the more time they invest in finding out how it is structured, the less time and energy they use to learn the content, according to Trammell and LaForge (2017).

In summary, andragogy asserts that the adult needs information in three areas: how learning will take place, what learning will take place, and why learning is important (Knowles et al., 2020).

The Role of Experience as a Resource for Learning

According to Knowles (1990, p. 31): “Experience is the richest resource for adult learning; therefore, the main methodology of adult education is the analysis of experience”. For pedagogy, the learner's experience is of little value for learning; the experience that counts is that which the teacher helps to generate and the didactic resources he or she selects. On the contrary, adults come to the learning situation with a large volume and different quality of experience than children and young people (Knowles, 1980). This implies, on the one hand, that the adult learner group is more heterogeneous in terms of motivation, interests, and goals and, on the other hand, that for some types of learning the richest resource may lie in the learner himself/herself, in his/her experience and prior knowledge which can be used to enhance the learning process (Kleinke & Lin, 2020).

Knowles et al. (2020) consider the adult learner's experience as a resource from which to draw information, relate it and apply it to study material, so teaching will be more effective if it is based on the adult's experience. Therefore, the adult learner's life and professional experience are significant starting points for planning university studies (Valli et al., 2017). Adult learners actively seek to apply their experiences in a practical context (Kleinke & Lin, 2020).

However, not all prior experience is of equal value for highly specialized and technical learning. Prior knowledge, and students' experience in the work sector covered by the PGCE, may be an advantage regarding conceptual mastery and practical problem-solving strategies compared to experience gained in other fields of knowledge, making the material more relevant for the former than for the latter, who would need a higher degree of guidance from the lecturer (van Riesen et al., 2018).

METHODOLOGY

This study is part of the project *Digital Andragogy in the 21st Century*. Specifically, this study focuses on the analysis of two of the andragogical principles proposed by Knowles (1980): the *need to know* (NK) and the *role of experience* (RE). The objectives of this study are: 1st To test the theoretical validity of these two principles of Knowles' theory through 21st century online learners' evaluations of the different didactic strategies that relate to these principles; 2nd To identify whether there are significant differences in terms of different age groups' valuation of these strategies, and the relationship with their experience and employment status (whether they are currently employed or not) and 3rd To explore gender differences in these preferences.

To achieve these objectives, a mixed method is used, starting with a quantitative method (questionnaire), followed by a qualitative method (interview) involving a more detailed exploration with a few individuals (Creswell, 2009).

Participants

The research was approved by the university's ethics committee. The sample consisted of online PGCE students from a private Spanish university. The socio-economic level of the students is between medium and medium-high. The questionnaire was presented to the students in the virtual face-to-face sessions and in the platform's forums during the second semester of the 2021-2022 and 2022-2023 academic years, to a total of 470 students, of which 245 completed the questionnaire. The university's pedagogical model promotes self-directed learning with the guidance of the teaching staff, who work from online forums and sessions, whose recordings are stored in the LMS. In addition, students also have access to a syllabus with the basic content of the subjects and various teaching aids such as complementary texts and audiovisual resources. Table 1 shows the demographic data of the sample.

Table 1

Demographic data of the questionnaire sample

		%	Number of cases
Gender	Woman	67,34	165
	Man	31,83	78
	Other	0,81	2
Age (N=244) *	>25	14,75	36
	26-45	71,72	175
	<45	13,52	33
Previous Studies	Health Sciences	23,67	58
	Engineering	28,16	69
	Humanities	11,83	29
	Life Sciences	13,46	33
	Social Sciences	18,36	45
	Math	1,63	4
	Architecture	2,85	7
Any related job?	No	79,18	194
	Yes	20,81	51

Note: Composed by the authors. One of the students didn't answer about his/her age.

Only 14.75 % of the student body in the sample can be considered traditional according to the age criterion. Most of the sample is female (67.34%).

As a complement to the questionnaire, individual online interviews were conducted with five students who were in their second semester in the academic year 2022-2023, which in practice means that they have successfully completed all subjects of the PGCE. The demographics of this group are shown in Table 2.

Table 2

Demographics of the interview sample

Student	Age	Gender	Qualification	Employed	Experience in Education
A1	42	M	Telecommunications Engineering	Yes	No
A2	26	F	Social Education	Yes	Yes
A3	32	F	Social Work	No	No
A4	27	M	Social Work	Yes	No
A5	26	M	Industrial Design and Product Development Engineering	Yes	No

Note: Composed by the authors.

Instrument

For this research a questionnaire was designed (CAIPA-v1; Questionnaire of Self-identification with Andragogical Principles), which consists of two sections: the first one collects demographic data of the sample, the second one is made up of 19 questions oriented to know the student's self-identification with Knowles' andragogical principles. The response options are graded on a four-value Likert scale to avoid central tendency bias: 1- Strongly Disagree; 2- Disagree; 3- Agree; 4- Strongly Agree.

The Scale Content Validity Index (S-CVI) was applied to assess the relevance and representativeness of the questionnaire items, reaching an S-CVI/Ave of 98.61%, whereby, on average, a high percentage of the 6 experts who were consulted agreed with the relevance of each item. Additionally, an S-CVI/UA of 95.83% indicates that a considerable proportion of items received unanimous agreement from the experts. These indices exceed commonly accepted thresholds for confirming content validity, providing robust empirical evidence for the validity of the questionnaire (Haynes et al., 1995; Polit et al., 2007).

To determine the suitability of the data for exploratory factor analysis, a Kaiser-Meyer-Olkin test of sampling adequacy measure was performed, resulting in a KMO value=.82; additionally, Barlett's test of sphericity showed a χ^2= 168.93, *DoF*=28, $p<.001$, thus justifying the use of factor analysis with the sample data. Two eigenvalues greater than 1 were found (1st factor=3.47 and 2nd factor=1.05); these two main factors explain 56% of the total variance. Using a principal axis factor extraction method, with a Promax rotation and Kaiser normalization, the factor correlation matrix shows a value outside the main diagonal equal to .145, indicating a low correlation between factors. Table 3 shows a clear respective identification of each of the factors found.

Table 3
Terms of the factor structure of the questionnaire items

Andragogical Principles	Questionnaire's Items	Structural Terms (PCA, Promax rotation)	
		1st. Factor	2nd. Factor
Need to Know (NK)	NK1: I think it is important to know at the beginning of the subject how the contents are related to the exercise of the profession.	,809	,175
	NK2: I consider it useful for the teacher to explain at the beginning of the subject the objectives, its structure, and how to approach it to optimize the time spent.	,798	,136
	NK3: The main didactic objective of this PGCE must be to prepare me to solve everyday problems that arise at work.	,796	,185
	NK4: I consider it useful that at the beginning of the subject the teacher explains what their online sessions will consist of, their teaching style and how the sessions will help me successfully pass the subject.	,620	,213
Role of Experience (RE)	RE1: The activities that are most useful for me to learn are the exercises in which I can apply knowledge and/or my experience.	,112	,605
	RE2: It helps me understand the syllabus when the teacher gives real-life examples that I can relate to my personal or professional experience.	,134	,601
	RE3: I positively value activities that make me reflect on my previous knowledge and experiences.	,139	,585
	RE4: Activities that present good professionals as models arouse my interest.	,218	,512

Note: Composed by the authors.

The feasibility of Cronbach's alpha reliability analysis is supported by the existence of an eigenvalue greater than 3 (Yurdugül, 2008) and by exceeding the minimum sample size (22<*N*=245). The latter has been calculated according to Bonett (2002) based on a null Cronbach's alpha value in the null hypothesis (CA_0), an expected Cronbach's alpha value CA_{1E} =.7, with 4 questionnaire items per construct, a type I error probability α=.05, and a power of 90%. For the constructs of the need to know and the role of experience, Cronbach's alphas of CA_{NK} =.85 and CA_{RE} =.79 were obtained respectively, which are valid for research (Streiner, 2003).

For the present analysis, students were grouped into three age groups, traditional <25 years old, non-traditional 26–45 years old, and non-traditional >45 years old.

Responses are grouped and analysed according to Knowles' principles. For a detailed item-by-item analysis of the questionnaire, individual interviews were used.

For the design of the questions, the operational definition of the target principles of this study was as follows:

- NK: the adult learner needs to know before embarking on learning how the subject relates to the profession, what the objectives are, how the content is structured, how much time will be needed to complete it and what the online sessions will consist of and how they will support their learning.
- RE: the adult learner prefers activities that he/she can connect to real-life problems, that he/she can relate to his/her experience, and in which he/she can make use of it to acquire practical and reflective learning.

RESULTS

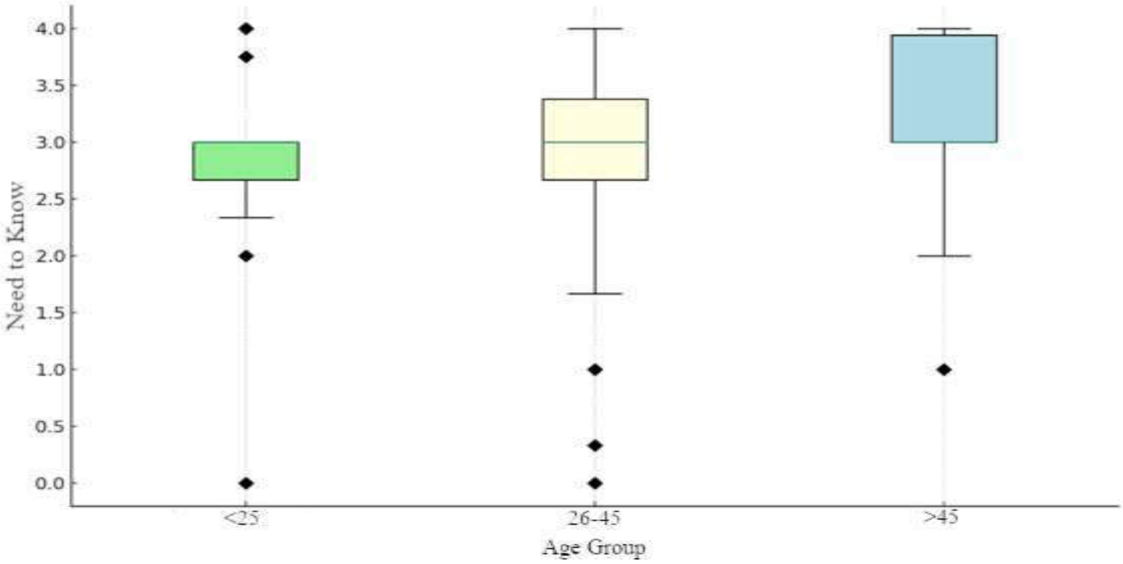
Descriptive and Inferential Analysis of the Questionnaire Responses

Using descriptive and inferential non-correlational statistics, the aggregated data from the CAIPA-v1 questionnaires of the non-experimental, retrospective, and cross-sectional research were analysed in the sample (*N*=245). The analytical tools used were SPSS version 29, and the Python libraries SciPy 1.11.1, and Matplotlib 3.7.2.

Figure 1 shows the distribution of the NK variable for each age group in the sample.

Figure 1

Distribution of NK by age groups



Note: Composed by the authors.

For the under 25 age group, most of the values are around the median 3, with a low dispersion (*SD*=0.60), which is seen in the interquartile range, which is the smallest of the three age ranges.

The group between 26 and 45 years shows a slightly wider distribution of values, with a median also around 3. However, this group has a higher dispersion (*SD*=0.77) compared to the group under 25 years, suggesting a higher variability in NK in this age group.

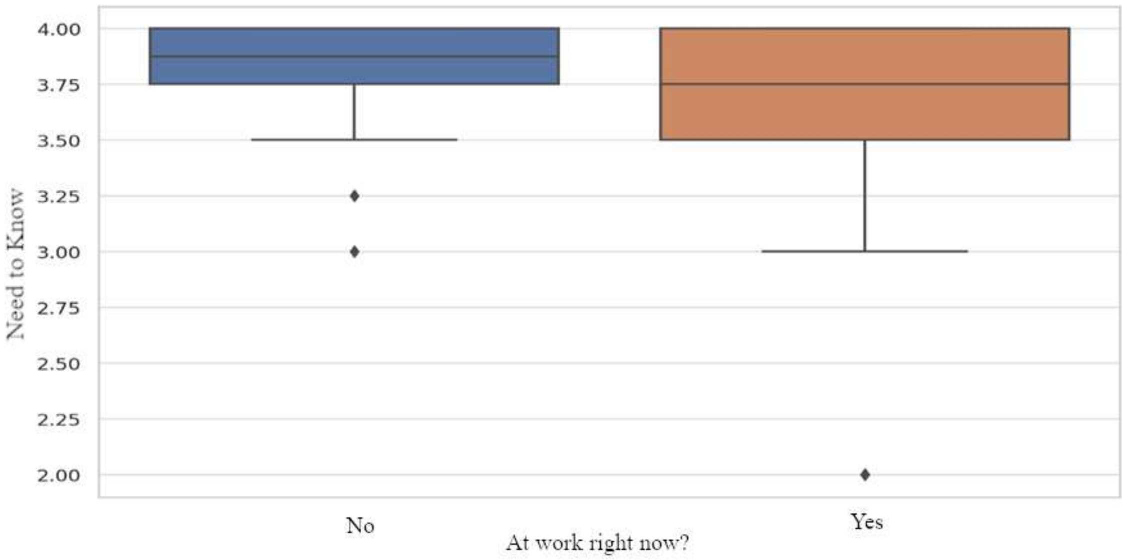
The group over 45 also shows a median of 3, but with a slightly higher dispersion (*SD*=0.76) than the group under 25, and close to that of the group between 26 and 45.

All age groups have a median NK of 3. This could indicate that the NK is similar in all age groups, although the variability of this need seems to be lower in the younger age group, which could imply a greater consensus for the traditional student group. However, there is not enough evidence to conclude that there is a significant difference in the NK between the different age groups, since by means of a Kruskal-Wallis test $H(n_{<25}=29, n_{26\text{-}45}=183, n_{>45}=34, p=.09)=4.76$ it can be concluded that no statistically significant differences in NK are found in the sample in the three groups.

Figure 2 shows that the median NK is high, close to 4. The interquartile range extends approximately from 3.5 to 4, indicating that the middle half of the employed persons' responses are in this range. However, the interquartile range is wider, which seems to indicate a higher variability in the responses of the unemployed; however, a Mann-Whitney test $U(n_{yes}=61, n_{no}=14, p=.50)=399$ indicates that it is not possible to state that there is a different distribution with statistical significance between the two groups in the analysed sample.

Figure 2

Distribution of NK according to employment status



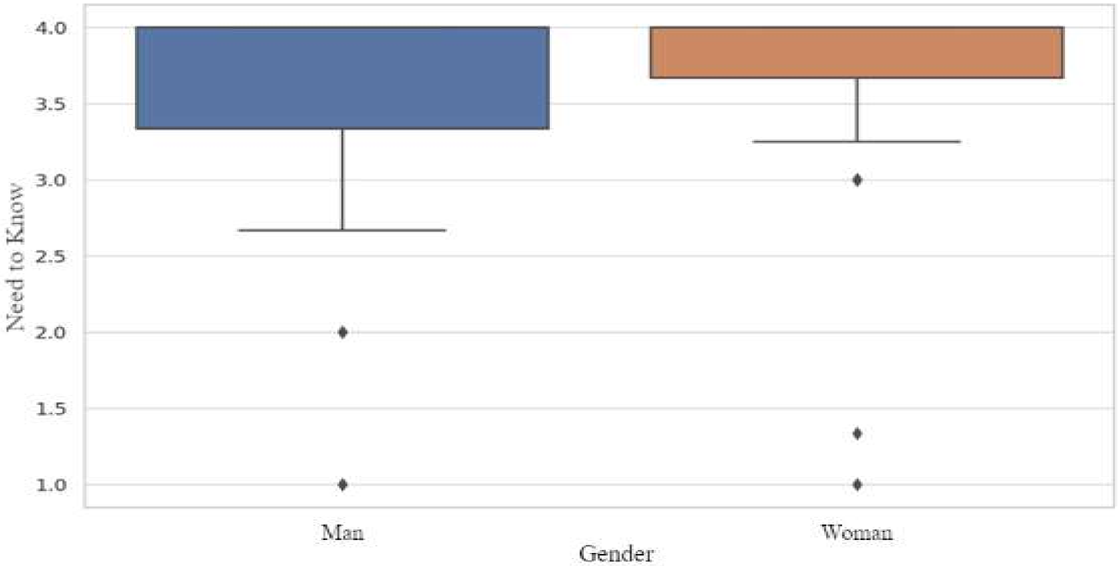
Note: Composed by the authors.

Figure 3 shows the comparison of responses on NK according to gender. Both groups show high NK. For males, the median is 4, and the interquartile range extends approximately from 3.33 to 4. For females, the median is also 4, and the interquartile range extends approximately from 3.67 to 4. According to the diagram, there seems to be a higher variability in the responses among males (*SD*=0.82) compared to females (*SD*=0.42).

However, a Mann-Whitney test $U(n_{woman}=165, n_{man}=80, p=.24)=6013.5$ indicates that it is not possible to state that there is a different distribution of NK with statistical significance between the two groups in the sample analysed.

Figure 3

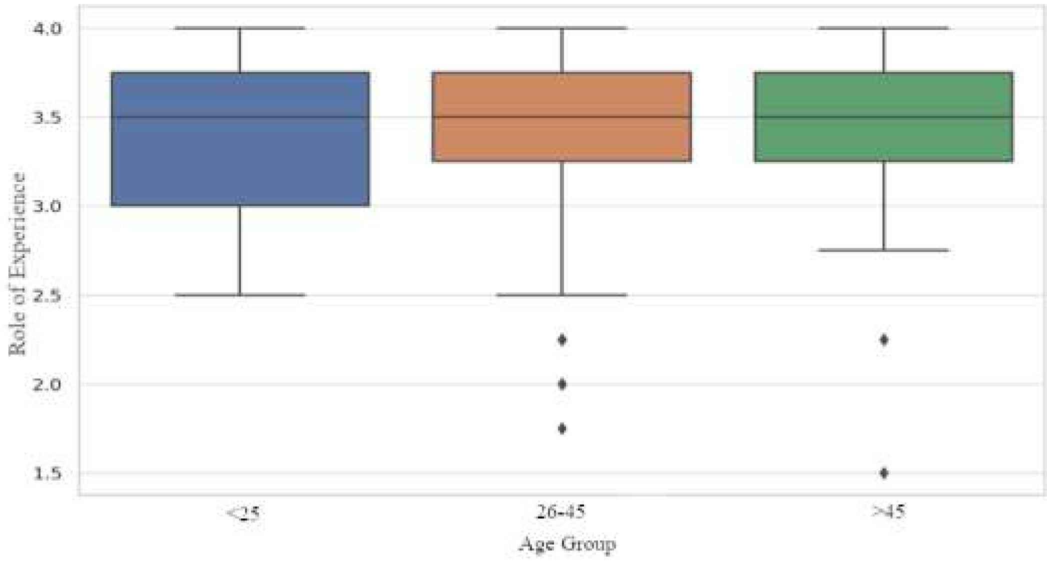
Distribution of NK according to gender



Note: Composed by the authors.

Figure 4 shows the RE between the different age groups. It can be seen that the three age groups show a similar distribution, with medians close to 3.5. It is interesting to note that the interquartile range is wider in the under-25 age group than in the other groups, which indicates a greater variability in the values within this age group, although its standard deviation is the smallest of the three groups (*SD*=0.41). On the other hand, the 26–45 and 45+ age groups show greater consistency in their responses, although they show larger deviations compared to the younger age groups, *SD*=0.47 and *SD*=0.53 respectively. In general, there does not seem to be a notable difference in the sample concerning RE between the different age groups, and by means of a Kruskal-Wallis test $H(n_{<25}=29, n_{26-45}=183, n_{>45}=34, p=.92)=0.16$ it can be concluded that no statistically significant differences can be found in the sample concerning the RE principle in the three groups.

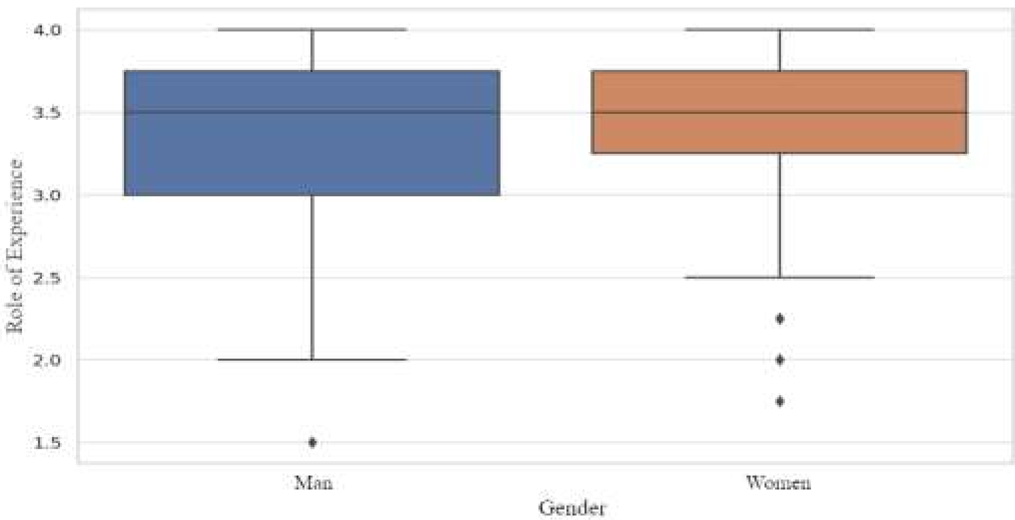
Figure 4
Distribution of RE between age groups



Note: Composed by the authors.

It can be seen in Figure 5 that both genders show a distribution of RE with medians of 3.5. The values in both genders vary mainly between 3 and 4, with some outliers. It is interesting to note that females have a somewhat narrower interquartile range than males, indicating a higher variability in males (*SD*=0.49) compared to females (*SD*=0.46). Overall, there does not seem to be a significant difference in SP between the different genders according to the sample observations, and a Mann-Whitney test $U(n_{female}=165, n_{male}=80, p=.63)=6930$ indicates that it is not possible to state that there is a different distribution with statistical significance between the two groups in the sample analysed.

Figure 5
Gender distribution of the role of experience

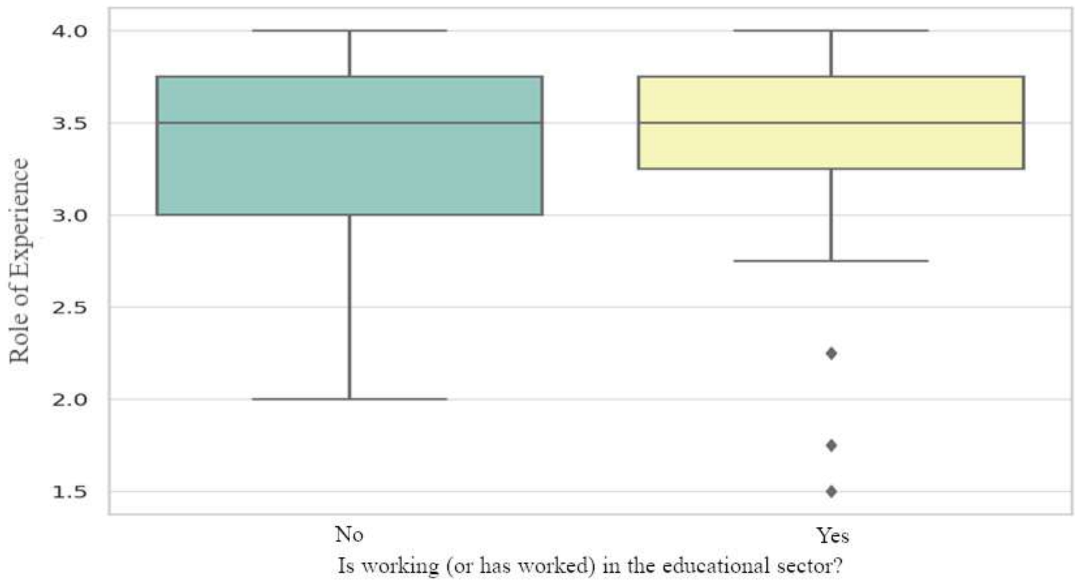


Note: Composed by the authors.

Figure 6 shows the distribution of RE according to previous experience. The distribution of scores is quite similar for both groups: both have the same median, interquartile ranges, and dissimilar overall ranges. Using a Mann-Whitney test $U(n_{yes}=96, n_{no}=150, p=.04)=8296$, we can say that there is a different distribution with statistical significance between those who work or have worked in the sector and the group that does not work or has not worked in the sector. Those who do not work or have not worked in the sector indicate a lower average of the role of experience ($M=3.38$, $Mdn=3.5$) than those who work or have worked in the sector ($M=3.48$, $Mdn=3.5$).

Figure 6

RE according to previous experience in education



Note: Composed by the authors.

Interviews

To obtain more in-depth information about the responses to the questionnaire, a member of the research team conducted individual interviews with the five selected students who had previously agreed to participate. To keep to the interview time agreed with the participating students (20 minutes), one item had to be removed from the original instrument out of the four items that make up each principle analysed in this study. It was decided to eliminate the one that contributed least to the reliability of the quantitative instrument used (CAIPA-v1). The questions selected from the quantitative instrument show a Cronbach's alpha $CA_{NK}=.787$ and $CA_{RE}=.752$.

The interviews were conducted online via *Adobe Connect*. The students were asked to rate the degree of agreement with the statement contained in the item according to the Likert scale, and to elaborate an explanation of why and/or how the situation in the corresponding item occurs in their case. The researcher then verified the response by obtaining a synthesis for transcription. Table 4 shows a selection of the most significant comments on the NK principle items.

Table 4

Results of the interviews on the items corresponding to the NK principle

Questionnaire items	Valuation	Comments to the items
1. I think it is important to know at the beginning of the course how the contents relate to the practice of the profession.	A1 - 3	"The legislation, the curriculum, the organizational documents... it doesn't matter so much that it's at the beginning as that it's being done. The virtual learning environments, and the technologies, have helped me and were very present in the master's degree".
	A2 - 4	"How the school is organized with the organizational documents (PEC, ...) thanks to this I have been able to collaborate in their elaboration in the school. I already knew what it was like to study by distance learning, and this has helped me to organize myself".
	A3 - 4	"It helps me to make logical sense of the subject and to find motivation in it".
	A4 - 4	"It makes sense of the content and that helps me to memorize and makes me less lazy".
	A5 - 4	"It gives you a context of possibilities and tools that you have to be able to practice".
2. I consider it useful for the teacher to explain at the beginning of the subject the objectives, its structure, and how to approach it to optimize the time devoted to it.	A1 - 2	"The objectives are already set, I think it is more important the timing and the structure, the methods, the practice, or theory, the work to be handed in".
	A2 - 3	"To optimize time, it seems significant to me the structure and the activities to be delivered, to organize yourself at your own pace".
	A3 - 4	"It helps me to organize my time".
	A4 - 4	"It's good because the people who work online help you to outline in your mind to get an idea of what it's going to take to study the subject. It's basic".
	A5 - 4	"It allows me to approach the subject more efficiently".
3. The main didactic objective of this master's degree is to prepare me to solve everyday problems in the profession.	A1 - 2	"You will be prepared to have an overview, to be comfortable, to be able to understand how a centre is structured, it goes beyond problem-solving, it's not all about problems".
	A2 - 2	"The master's degree provides basic theoretical knowledge, not only to solve problems, but also to prevent them".
	A3 - 2	"Everyday difficulties are a small part of the teaching profession".
	A4 - 2	"The problems are more for practice, and when it's your turn to be a teacher. Every school, classroom, and region is different, you learn these issues with experience".
	A5 - 3	"Agreed, but not the main objective, but also the general way of dealing with the profession, teaching, evaluation, etc."

Note: Composed by the authors.

In the answers to item 1 (relation of the contents to the profession), the terms "meaning" and "context" (A3, A4, A5) stand out.

In the responses to item 2 (information on structure and how to approach it), students emphasize the importance of knowing the structure and timing. Particularly, it seems important to know at the beginning of the subject the amount and timing of continuous assessment activities, which allows them to deal with it more efficiently by making work and study compatible.

Question 3 (the main objective of the PGCE is to learn to solve problems) was the question with the highest level of disagreement (2 points). Students considered that the day-to-day problems of the teaching profession are a minimal part of what teaching entails, so they appreciate that basic theoretical aspects and a broader view of the profession are also addressed in the PGCE.

Table 5 summarizes the comments to the questions on the RE principle.

Table 5

Results of the interviews for the items corresponding to the RE principle

Questionnaire items	Valuation	Comments to the items
4. The activities I find most useful for learning are exercises where I can apply my knowledge and/or experience.	A1 - 4	"It relates to meaningful learning, what you already know you relate to the theory."
	A2 - 4	"The exercises with which I learn the most are the practical ones. I don't seem to learn anything from the theoretical ones, I need to know what they are for."
	A3 - 4	"This is meaningful learning, when you apply what you have learnt. Especially in my dissertation, I am a social worker and I based it on a community project."
	A4 - 4	"They bring you closer to reality than just theory in text."
	A5 - 2	"My way of learning..., I learn by heart, even if it is more useful, in my case it doesn't apply, I prefer concepts."
5. It helps me to understand the syllabus when the teacher gives real-life examples that I can relate to my personal experience.	A1 - 4	"We always remember the anecdote or the story, it is easier to remember something real than pure theory."
	A2 - 4	"So the teacher brings the theory closer to real life ... to your reality, you visualize it, it helps you to put yourself in the situation, it's more effective."
	A3 - 4	"When you relate any content to an example, it is much easier to visualize and understand."
	A4 - 4	"Anything that has to do with relating content to reality is a shortcut to internalizing learning and learning skills."
	A5 - 4	"The more conceptually abstract subjects... giving real examples helps me to understand concepts and how they relate to reality."

6. I appreciate activities that make me reflect on my previous knowledge and experiences.	A1 - 3	"Yes, it makes you dig into what you already know and matches what you are learning."
	A2 - 3	"I like activities that awaken the desire to learn more, that make me realize that I need to learn more."
	A3 - 4	"They encourage debate, criticism, sharing ideas with colleagues and teachers."
	A4 - 3	"It can help you learn to compare the point of view I had as a student and later as a teacher."
	A5 - 4	"Studying teaching makes you look at your own learning experience as a student and analyze it from the point of view of a teacher. You think about things I would change about my teachers or, on the contrary, things that were done well."

Note: Composed by the authors.

Regarding item 4 (activities applying knowledge and/or experience), the terms "meaningful learning" (A1, A3) and "close to reality" (A4), "knowing what it is for" stand out. Only the younger students prefer more conceptual content, which facilitates memorization, to practical exercises.

As for the answers to item 5 (real-life examples), all five students agree that it is an important factor for their learning that the teacher gives examples of the concepts related to reality. The following terms stand out: "memorizing" (A1), "internalizing" (A4), "visualizing" (A2 and A3) and "understanding" (A3, A5).

Item 6 (reflecting on previous knowledge and experience) did not receive the same unanimity, although the responses are between 3 and 4. It is noteworthy that "realizing that you need to know more" is a motivating factor for A2. Also, that A4 and A5, having no teaching experience, compare the content of the PGCE with their experience as students and assess the teachers they had in the light of the new knowledge. Student A3 points out that this type of activity encourages debate, criticism, and the sharing of ideas with peers.

DISCUSSION AND CONCLUSIONS

The present study aimed to analyze how learning preferences and strategies are distributed among different profiles of online learners in terms of age and gender, employment status, and previous experience through self-identification with two of the andragogical principles proposed by Knowles (1980): NK and RE. The specific objectives were: 1) To test the theoretical validity of these two principles of Knowles' theory through 21st-century online learners' evaluations of the different didactic strategies that relate to these principles; 2) To identify whether there are significant differences in terms of different age groups' valuation of these strategies, and the relationship with their experience and employment status (whether they are currently employed or not); and 3) To explore gender differences in these preferences.

Regarding the first objective, a review of the literature on the adult and online learner has made it possible to operationalize Knowles' principles in items related to teaching and learning strategies. The results contribute to reaffirming the usefulness of andragogy in understanding how adult online university students learn. The basic principles of adult learning do not seem to be affected by the non-face-to-face nature of the online classroom, only the form of the technology-mediated teaching-learning process (Johnson, 2014). Students in this study value information that gives them an idea of how much effort and time they have to put in (Sun & Chen, 2016), what is expected of them, and what to expect from the teacher (Bailey & Card, 2009), how the subject is structured (Trammell & LaForge, 2017), how it makes sense and why it is important (Knowles et al., 2020) for the profession. Regarding the RE in learning and the orientation of learning to solve real-life practical problems, it can be concluded from the interviews that students value activities of this type with a score between 3 and 4, in contrast to the study by Kennan et al. (2018) who did not find students' need to connect their learning to the real world, the job, or experience. However, the students in this study also expect the training they receive to go beyond technical training to solve everyday problems in the teaching profession. In general, it can be said that students use strategies related to Knowles' principles. These results confirm those found by Aljohani and Alajlan (2021) and by Rodrigo et al. (2024), as well as the studies analysed by Puwarti et al. (2022).

Regarding the second specific objective, no significant differences were found between the three age groups, although the 26-45 age group is the most heterogeneous since among the students in this group there are closer responses to 2 compared to the students in the other two groups, although this may be due to the fact that it is also the largest age group and therefore the most heterogeneous in terms of previous online experience, which seems to be an important factor in choosing this type of training (Henrikson & Baliram, 2023) and in organizing their time (A1 and A2). These results seem to confirm that culture, learning environment, and life experiences may be more significant determinants of how people learn than age (Knowles, 1980).

In terms of gender distribution, no significant differences were found in any of the principles, although in the group of women, a lower variability of responses was found, all close to 4 in both principles. Therefore, concerning the criticism of the male bias of andragogical theory (Moll, 2023), in the sample analysed, the assumptions of andragogy would be equally or more valid than for the male gender, particularly about the need to know. This result is in line with Aljohani and Alajlan (2021) and could be interpreted as a greater need to organize their time efficiently due to family responsibilities. In Roessger et al. (2020) preferences for andragogical principles were higher for men with education above secondary school and from highly qualified professions. In Kennan et al. (2018) no differences were found according to socio-economic status. The private university context in this study and the access requirement of university qualification together with a female majority makes the sample more homogeneous in this respect. Therefore, concerning the critique of class bias, gender, and cultural differences (Moll, 2023; St. Clair & Käpplinger, 2021) in their approaches we are inclined to think, in the light of the results, that class and the level of qualification of the student body may have more influence than gender on the preferences about the pedagogical model of the study programme.

As for the RE principle, a significant effect was found according to experience in the education sector. Surprisingly, inexperienced learners place a higher value on activities that use prior experience as a learning resource, as opposed to more experienced learners, which seems to contradict the principle of andragogy and the claim that adult learners actively seek to apply their experiences in a practical context (Kleinke & Lin, 2020). However, this could be interpreted as the former's need for a higher degree of guidance from the teacher (van Riesen et al., 2018) to make practical sense of the content as they lack references from actual practice. The quantitative analysis indicates a greater dispersion of responses to this principle in the group <25 years old, which logically coincides with less or no work experience, and which uses their experience as a student as a resource or strategy (A4 and A5).

The LMS often reduces the teacher's freedom in the curricular design of the courses they teach (Baldwin et al., 2018), however, the improvements in student-content and student-teacher interaction proposed in this study through the questionnaire items and interviews conducted can improve satisfaction, online student academic outcomes and reduce dropout (Ke & Kwak, 2013; Kuo et al., 2014) and are within the scope of the online teacher.

One of the limitations of this study is the absence of an analysis of the variable of the degree with which students access the PGCE, which could yield alternative distributions in terms of the strategies used by students. Another limitation is the size of the sample, which does not allow us to generalize the findings to the entire population of students who choose an online education in Spain.

However, the constructed instrument has been confirmed as valid and reliable in the approach to digital andragogy, to develop a valid theoretical framework for the training of today's adults in virtual environments.

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