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ARTIFICIAL INTELLIGENCE AND COMPUTATIONAL THINKING IN A CROSS-CURRICULAR EXPERIENCE IN SECONDARY EDUCATION: BENEFITS ON STUDENT'S ACADEMIC PERFORMANCE AND MOTIVATION

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ABSTRACT: Computational thinking (CT) and artificial intelligence (AI) are emerging technologies that can personalize learning and prepare students for current challenges. This study examines how an active methodology, based on a competency-based approach, enhances students' knowledge of CT and AI while increasing their motivation in the subjects of Technology and Digitalization, and Biology and Geology, in the third year of Secondary Education (3rd ESO). The study was conducted across both subjects with 119 3rd ESO students. A mixed-methods approach was used. The first phase was quantitative, employing a quasi-experimental design. Initially, students' levels of CT, AI, and Digital Competence were assessed through a pretest. Subsequently, an innovative methodology was implemented in the experimental group, while the control group covered the same content using traditional methods. A post-test was then administered to compare the learning outcomes in CT, AI, and Digital Competence between the two groups. The second phase was qualitative, focusing on content analysis through an ad hoc questionnaire that gathered the opinions of teachers and students involved in the educational experience. The results indicate that students who engaged with AI in both subjects improved their understanding and practical knowledge of CT and AI, demonstrated higher motivation towards learning, and felt capable of designing their own educational resources with appropriate support. Additionally, projects that integrate ICTs transversally promote motivation, learning, and the development of competencies in students.

KEYWORDS: computational thinking, artificial intelligence, secondary school, motivation, academic performance.

INTELIGENCIA ARTIFICIAL Y PENSAMIENTO COMPUTACIONAL EN UNA EXPERIENCIA TRANSVERSAL EN EDUCACIÓN SECUNDARIA: BENEFICIOS EN EL RENDIMIENTO ACADÉMICO Y LA MOTIVACIÓN DEL ALUMNADO

RESUMEN: El pensamiento computacional (PC) y la inteligencia artificial (IA) son tecnologías emergentes que pueden personalizar el aprendizaje y preparar a los estudiantes para los desafíos actuales. Este estudio analiza cómo una metodología activa y basada en un enfoque competencial mejora el conocimiento en PC e IA y aumenta la motivación de los estudiantes en Tecnología y Digitalización, y Biología y Geología, en 3º de ESO. El estudio se realizó de manera transversal en ambas asignaturas con 119 alumnos de 3º de ESO. Se utilizó una metodología mixta. En la primera fase, de carácter cuantitativo, se empleó un diseño cuasiexperimental. Primero, se evaluó el nivel en PC, IA y Competencia Digital mediante un pretest. Luego, se implementó una metodología innovadora en el grupo experimental, mientras que el grupo de control trabajó los mismos contenidos con una metodología tradicional. Posteriormente, se realizó una evaluación post-test para comparar los aprendizajes en PC, IA y Competencia Digital en ambos grupos. La segunda fase fue cualitativa, centrada en un análisis de contenido mediante un cuestionario ad hoc que recopiló las opiniones del profesorado y del alumnado involucrado en la experiencia educativa. Los resultados indican que los alumnos que trabajaron con IA en ambas asignaturas mejoraron su comprensión y conocimiento práctico de PC e IA, demostraron mayor motivación hacia el aprendizaje y se sintieron capaces de diseñar sus propios recursos educativos con el apoyo adecuado. Además, los proyectos que integran las TIC de manera transversal favorecen la motivación, el aprendizaje y el desarrollo de competencias en los estudiantes.

PALABRAS CLAVE: pensamiento computacional, inteligencia artificial, Educación Secundaria, motivación, rendimiento académico.

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EXTENDED ABSTRACT

This study investigates the integration of computational thinking (CT) and artificial intelligence (AI) into the curriculum of 3rd-year secondary education students, focusing on the subjects of Technology and Digitalization, and Biology and Geology. The research aims to evaluate the impact of these emerging technologies on students' academic performance and motivation. A mixed-methods approach was employed, involving 119 students and utilizing a quasi-experimental design. The experimental group engaged with innovative methodologies incorporating CT and AI, while the control group followed traditional teaching methods. Pre-and post-tests assessed students' knowledge in CT, AI, and digital competence.

Educational innovation, particularly using emerging technologies, is crucial for enhancing learning outcomes and preparing students for future challenges. This study explores how active, competency-based methodologies can improve students' understanding of CT and AI and increase their motivation in secondary education. The research was conducted with 119 students in the 3rd year of ESO (Educación Secundaria Obligatoria) in Spain, across the subjects of Technology and Digitalization, and Biology and Geology.

A mixed-methods approach was used, comprising both quantitative and qualitative phases. The quantitative phase involved a quasi-experimental design with pre- and post-tests to measure students' levels of CT, AI, and digital competence. The experimental group was exposed to an innovative methodology that integrated CT and AI into the curriculum, while the control group followed traditional teaching methods. The quantitative phase employed a quasi-experimental design to evaluate the impact of the innovative methodology on students' knowledge and skills. Initially, students' levels of CT, AI, and digital competence were assessed through a pretest. The experimental group then engaged with an active, competency-based methodology that integrated CT and AI into the curriculum. This approach included hands-on activities, project-based learning, and the use of digital tools such as Scratch and LearningML. The control group, on the other hand, followed traditional teaching methods, focusing on textbook-based instruction and problem-solving exercises. After the intervention, a post-test was administered to both groups to compare their learning outcomes.

The qualitative phase involved content analysis of questionnaires administered to teachers and students. These questionnaires aimed to gather their opinions on the educational experience, including their perceptions of the innovative methodology, its impact on their motivation and learning, and any challenges they encountered. The qualitative data provided valuable insights into the subjective experiences of the participants and complemented the quantitative findings.

The results indicated significant improvements in the experimental group's understanding and practical application of CT and AI. Students in the experimental group demonstrated higher motivation towards learning and felt more capable of designing their own educational resources with appropriate support. The pre- and post-test comparisons revealed that the experimental group showed greater gains in CT, AI, and digital competence compared to the control group.

The analysis of the pre- and post-test results for CT revealed that the experimental group showed a statistically significant improvement in their scores compared to the control group. This suggests that the innovative methodology, which emphasized hands-on activities and project-based learning, effectively enhanced students' computational thinking skills. The experimental group demonstrated a better understanding of key CT concepts, such as algorithmic thinking, problem decomposition, and pattern recognition.

The results for AI knowledge and skills also showed significant improvements in the experimental group. The post-test responses indicated that students in the experimental group had a more precise and nuanced understanding of AI concepts and their applications. For example, students were able to articulate the definition of AI more accurately and

identify its potential risks and benefits. The hands-on activities and projects involving AI tools, such as LearningML, helped students develop practical skills and a deeper understanding of AI.

The analysis of digital competence scores revealed that the experimental group showed a greater increase in their scores compared to the control group. Although the improvement was not statistically significant, the trend suggests that the innovative methodology had a positive impact on students' digital competence. The experimental group demonstrated better skills in using digital tools, collaborating online, and creating digital content.

The qualitative analysis of the questionnaires revealed that both teachers and students had positive perceptions of the innovative methodology. Teachers reported that the cross-curricular approach and the integration of CT and AI enhanced students' engagement and motivation. They also noted that the methodology encouraged collaboration and critical thinking. Students expressed that the hands-on activities and projects made learning more enjoyable and relevant to real-world applications. They appreciated the opportunity to work with digital tools and develop practical skills.

The findings suggest that integrating CT and AI into the curriculum through active, competency-based methodologies can enhance students' academic performance and motivation. The cross-curricular approach, combining Technology and Digitalization with Biology and Geology, provided a comprehensive learning experience that fostered critical thinking, problem-solving, and digital literacy. Teachers reported increased motivation and engagement among students, as well as a deeper understanding of the subject matter.

This study underscores the importance of incorporating emerging technologies like CT and AI into secondary education to prepare students for the demands of the modern world. The positive impact on students' academic performance and motivation highlights the potential of active, competency-based methodologies in fostering a more engaging and effective learning environment. Future research should explore the long-term effects of such interventions and the scalability of these approaches across different educational contexts.

The study highlights the need for teacher training in emerging technologies to ensure the successful implementation of innovative methodologies. Teachers should be equipped with the knowledge and skills to integrate CT and AI into their teaching practices effectively. Additionally, schools should provide the necessary resources and support to facilitate the adoption of these technologies. The findings also suggest that cross-curricular projects can enhance students' learning experiences by making connections between different subjects and promoting a holistic understanding of complex concepts.

Future research should investigate the long-term effects of integrating CT and AI into the curriculum on students' academic performance and motivation. Longitudinal studies could provide insights into how these methodologies impact students' learning outcomes over time. Additionally, research should explore the scalability of these approaches across different educational contexts, including primary education and higher education. Further studies could also examine the impact of teacher training programs on the successful implementation of innovative methodologies.

1. INTRODUCTION

1.1. Educational innovation, emerging technologies and competency-based learning

Educational innovation is related to improvement and change in education by generating effective modifications in learning and transferable outcomes to other contexts (García-Peñalvo and Ramírez-Montoya, 2017). It focuses on four areas (knowledge, people, methodology and technology) with a view to bringing about changes in teaching and learning processes in schools, particularly in terms of the methodologies and tools used. One of these tools is Information and Communication Technologies (ICTs) or Emerging Technologies. These technologies represent a considerable improvement in the educational process, providing resources that were previously unthinkable, both from the point of view of the teacher (Flores-Tena et al., 2021; Fombella-Canal, 2018) and the student (Fuentes-Cabrera and Sánchez-Romero, 2021; Martinenco et al., 2021). Research on educational innovations that use emerging technologies in the classroom shows an increase in student motivation, as well as improvements in their attitude towards education and better academic performance (González-Vidal, 2021; Zabala-Vargas et al., 2021).

Added to this is the competences approach in the teaching and learning processes proposed in the current Organic Act on Education (2020), LOMLOE, where the key competences are those essential skills for students to progress in their education and face future challenges. In the specific case of science subjects, this approach has provided a real opportunity to improve didactics (Jiménez-Alexandre, 2009; Pro, 2011), allowing science teaching to be oriented towards innovation and the challenges of today's world. This study proposes an experience that combines work on digital competence and competence in science, technology and engineering, as well as learning to learn, and a sense of initiative and entrepreneurship. The main objective is to develop critical thinking, problem solving and competency-based work.

1.2. Computational Thinking and Artificial Intelligence: learning benefits

CT is currently one of the most prevalent and controversial pedagogical concepts, which can be understood as a way of solving problems, designing systems, and understanding human behaviour by harnessing the potential of computers (Rodríguez-García et al., 2021; Román-González et al., 2017). The incorporation of this into the education system is extremely helpful in preparing students to face an increasingly technological job market, improving their complex problem-solving skills and providing solutions to new challenges in society. Literature reviews indicate that Spain is one of the countries with the highest number of publications on this topic (Roig-Vila and Moreno-Isac, 2020). Different experiences of applying

CT in the classroom have been found (Avello et al., 2020; Irgens et al., 2020; Noh and Lee, 2020; Saxena et al., 2020), as well as others related to teacher training in CT (Irgens et al., 2020; Kong et al., 2020). In fact, Juškevičienė (2020) claims that teachers are not sure how to carry out practical experiences in the classroom with these tools.

Artificial Intelligence (AI) is a basic tool for working within CT. Loder and Nicholas (2018, cited in Baker et al., 2019, p. 10) define it as "computers that perform cognitive tasks, normally associated with human minds, in particular learning and problem solving". Research has pointed to a clear relationship between AI classroom work and CT development (Van Brummelen et al. 2019). The Horizon Report (Becker et al., 2018) states that AI-based applications in education have grown by around 45% between 2018-2022 and exponential growth is expected. The report argues that their incorporation into the education system has been of great help in improving their complex problem-solving skills and providing solutions to new societal challenges, preparing students for an increasingly technological labour market. Similarly, UNESCO (2021) in its report on AI emphasises its importance for innovative learning, for combating social inequalities around the world, and as a powerful tool for achieving the Sustainable Development Goals (SDGs) through new educational models that enable personalised learning, anywhere and for everyone. AI is becoming a key element in understanding the digital competence needs of today's citizens (Vuorikari et al., 2022), highlighting a series of challenges posed by the widespread use of AI, including the ethical issues involved (UNESCO, 2023b).

AI-based tools are a reality in schools and are gradually helping in resource planning (Chatterjee and Bhattacharjee, 2020), or adapting content for students (Villegas et al., 2020; Xiao and Yi, 2020). There are numerous examples of machine learning in the classroom (Marques et al., 2020). Within these, there are several examples of the suitability of integrating MIT App Inventor with machine learning (Tang, 2019; Zhu, 2019).

Based on the above, the aim of the study is to analyse how students' CT and knowledge of AI improves when working with an active methodology based on a competency-based approach, while at the same time increasing student motivation in two specific subjects, such as Technology and Digitalisation, and Biology and Geology in the third year of Secondary Education. These are the following specific objectives:

1. To find out if there is a significant difference in the level of motivation between using an active methodology in AI and ICT work, versus traditional content learning.
2. To analyse the degree and depth of AI knowledge when AI is worked on in a more competency-based and cross-subject manner than when it is not.

3. To investigate how students perceive AI when they do it with more active and procedural methodologies, linked to ICT in learning, in their own learning and in that of their peers, as opposed to more traditional methodologies.
4. To analyse the opinions of the teachers of the subjects involved on the benefits of developing transversal learning designs, as well as their perceptions of their digital competence to deal with this innovation.
5. To test the effect on pupils' digital competence and scientific competence of applying a teaching proposal on AI based on active methodologies and ICT in a cross-cutting manner in two areas.

2. METHODOLOGICAL DESIGN

Using a mixed methodology, an initial quantitative quasi-experimental design (pre-post test) was applied to the experimental group, involving integrated work on AI and its practical application in a classroom proposal to create a rock and mineral recognition system for the subjects of Technology and Digitalisation, and Biology and Geology in the third year of secondary school (ESO). Therefore, the Technology and Digitalisation course aims to cover content related to AI, while Biology and Geology will focus on the study of rocks, which is the set of content around which the project is structured. Classroom work is carried out in the experimental groups with Scratch and LearninML and in the control groups with a traditional methodology centred on the textbook and problem solving. This way of working is applied in both subjects. Before the experiment and after finishing the implementation phase of the didactic proposals, the questionnaire to assess their CT skills, the AI Knowledge Test and the digital competence are completed. The analysis of the differences between the pre-test and post-test provides evidence of the skills and knowledge acquired during the experiment. Subsequently, there is a second qualitative phase, namely a content analysis of the questionnaires applied to teachers and students on the experience developed. A summary of the research phases is presented.

1. Assessment of CT, AI and digital competence of the experimental and control groups (Pretest).
2. Work on AI content in the control and experimental group (traditional vs. innovative methodology).
3. Post-test: CT and AI assessment test in both groups.
4. Teacher and student evaluation questionnaires (content analysis).

2.1. Sample selection

The work was carried out in a secondary school in Castilla y León. Groups of third-year secondary school students were used (convenience sampling). The sample consists of 119 pupils, most of whom are 14 years old. Of these, 65 are male and 54 are female. The classroom distribution is detailed in Table 1.

Table 1. *Distribution of the student body by section*

Sex	Section A	Section B	Section C	Section D	Total
Male	16	15	16	18	65
Female	14	16	13	11	54
Totals	30	31	29	29	119

The proposed didactic application, based on AI work in the subjects of Biology and Geology, and Technology and Digitalisation, will be carried out in the first 3 sections, with the fourth section being a control group that will work on the Biology and Geology unit using a more traditional methodology and not mediated with the use of ICTs. There are two teachers involved in this case: one from the Technology and Digitalisation subject and one from the Biology and Geology subject, both of whom teach all the groups.

2.2. Design of the didactic application: IDENTI-ROCK

The aim of this didactic proposal is the design of an application programmed by the students themselves using the AI tool, which is capable of recognising rocks and minerals. The idea is that the didactic proposal not only helps to develop specific dimensions of CT, but also to provoke learning in the contents of the curriculum of the corresponding areas. The specific objectives to be pursued with the pupils:

1. Work on mathematical competence and science, technology and engineering; and digital competence through the creation of a tool through AI.
2. Understand the concept of AI and reflect on how it can affect society at large.
3. Promote the critical use of technologies through project-based learning.
4. Enhance competency-based learning and the interrelation of content through a cross-curricular approach to Biology and Geology and Technology and Digitalisation, using AI.

Students are encouraged to be able to design and implement an AI application, which helps them to internalise the characteristics of these systems, their problems and possibilities, but also the risks they present when used. The ultimate intention is not that they should be experts in AI, but that they should be able to critically analyse its use and recognise the fields in which it is currently used and in which it can potentially be used (UNESCO, 2023a).

The challenge of visually identifying different rocks and minerals presents itself as a complex task for pupils that requires training time and that they usually find arduous and difficult. It is this difficulty that the development of the application is intended to circumvent. To do so, they must use an AI application, LearingML, which allows image recognition and Scratch as a programming language.

Scratch is a visual, block-based programming language that makes it easy to create video games, interactive stories and animations. It is particularly suitable for beginners in the world of programming and developing CT-related skills. The students have worked with Scratch in previous courses and are therefore familiar with its use.

LearningML is an initiative that was born in 2019 and seeks to bring the reality of machine learning to the educational world, while aiming to be a platform that can be easily integrated with programming languages designed for education and thus enable the development of more complex applications that integrate this type of AI.

As for how the project was organised, several meetings were held between the teachers involved to discuss the content to be covered, both in biology and geology, as well as in technology and digitalisation, particularly in relation to AI. Coordinated and joint work was carried out between both areas during the sessions that lasted the implementation of the proposal. The sessions took place without differentiating between classes in one subject or another.

When working in the classroom, the groupings will be diverse, so activities 1, 2 and 3 (table 2) will be carried out individually, while the development of the project will be carried out using programming in pairs (Revelo-Sánchez et al., 2018). The phases and activities into which the proposal is structured are as follows.

Table 2. *Phases of the "IDENTI_ROCK" project*

Initial Phase
Activity 1: Activation of prior knowledge Students will activate their prior knowledge of machine learning in this activity by examining the functions of applications with which they are familiar, although they will probably not have considered how these applications work.

Deepening phase
Activity 2: Train a machine learning model in LearningML. A highly directed activity that helps students become familiar with the computer tools that will be used. In addition, the concept of AI and its different types, such as machine learning, will be explored in depth. Activity 3: Model Biases Students will discuss in this activity how the sampling and evaluation of data for training can affect the outcome of a machine learning model.
Activity development phase
Activity 4: Programming with machine learning Students will practice group programming as a synthesis element to complete a LearningML project. In this project, they will train and integrate a machine learning model in Scratch. Activity 5: Final reflection Students should discuss this activity to reflect on their learning and consider the social impact of using AI in everyday applications.

2.3. Data collection instruments

Using a mixed methodology, the initial quantitative phase involved a quasi-experimental design and a pre-test/post-test evaluation to measure CT, AI and digital competence. Then, in a second qualitative phase, two ad hoc evaluation questionnaires with open-ended questions were administered to determine the degree of satisfaction of the teachers involved and the students who had participated in the experimental situation. The instruments used in data collection are listed below:

1. The Computational Thinking Test (TPC, in Spanish) (Román-González, 2015), which measures the development of CT, is specially designed for subjects between 12 and 14 years of age. It is a 28-item-long test in which each item is characterised by a combination of five dimensions: computational concept, environment, response style, nesting of computational concepts and task requested.

2. AI knowledge test (Estévez et al., 2019). It is composed of a total of 6 questions, two of which are open questions asking about what AI is and its risks, and the other four are formulated to be answered on a Likert scale with 5 responses (agree, disagree).

3. The student digital competence questionnaire ECODIES V2 (Hernández-Martín and Iglesias-Rodríguez, 2020) assesses digital competence by means of 40 items.

This test is structured according to the proposal of the European Commission DigComp 2.1 (Carretero et al., 2017) and is organised in 5 areas (Information and information literacy, Communication and collaboration, Digital content creation, Security and Problem solving) 4 levels (basic, intermediate, advanced, highly specialised) and 3 domains (knowledge, skills and attitudes). Although the European Commission has already published the DigComp 2.2 proposal (Vuorikari et al., 2022), this ECODIES test has not yet been updated to the new elements.

4. Ad hoc questionnaires for teachers: this is part of the qualitative evaluation, the aim is to find out their opinion and assessment of the didactic proposal applied in a transversal way compared to the traditional learning of the control group. The questions asked are shown in Table 3:

5. Questionnaire to students in the experimental group: this is part of the qualitative evaluation, the aim of which is to find out their opinion on the AI teaching experience in which they participated. The questions are attached below and summarised in Table 4.

Table 3. *Ad hoc questionnaire for teachers*

1. Before participating in the experience, were you aware of the pedagogical potential of AI to address didactic learning and the development of key competences in students?
2. How do you value the participation in the present experience: difficulty, usefulness for learning, strengths and weaknesses of the project?
3. How does it affect students' learning?
4. Would you like to use AI in the future in your subject?
5. What did you need to do it: training, support, group work?

Table 4. *Ad hoc questionnaire for students in the experimental group*

1. Prior to participation in the experience, had you been involved in any AI or CT projects?
2. What did you think of the project? It highlights the positive things and the things to improve.
3. How has your learning experience been? How has it changed?
4. Would you like to use AI in other subjects?

3. RESULTS

After obtaining the research data at various points in time, it was analysed using SPSS statistical software.

3.1. Analysis of the CT test results

To analyse the test on CT (TPC, Román-González, 2015), Cronbach's alpha (Brown, 2002) was used as an indicator which, applied to the pre-test and post-test, allows us to check the reliability of the results obtained. As can be seen in table 5, the values obtained are above 0.7, which is the limit set by the literature as adequate to ensure reliability (Oviedo and Campo-Arias, 2005).

Table 5 *Cronbach's Alpha results for CT Test*

	Pre-test values	Post-test values
Control group	0.81	0.75
Experimental group	0.89	0.91

This same indicator was used when analysing the AI Knowledge Test (Estévez et al., 2019), obtaining values of .72 - .75 and .77 - .76 for the control and experimental groups respectively. The data will be presented in groups based on the tool used to obtain it, in order to facilitate understanding.

Thus, the results obtained in this test are presented for both control and experimental groups, before and after having dealt with AI-related content. The values obtained are shown in Table 6. It should be noted that there is a statistically significant difference ($p= .01 < .05$), although of low intensity, in the sense of improving the results obtained in the post-test with respect to the pre-test. It is also interesting to observe the differences that appear between boys and girls when analysing the scores obtained, because the results obtained by girls are significantly lower than those of boys in all the situations of the experiment, although it is worth noting that the improvement in the post-test scores is of a greater intensity in girls than in boys (table 7). This analysis by sex has only been done for the experimental group, as the control group has a very small number of subjects, so that any differences found are not significant.

Table 6 *CT Test Results (Mean, maximum and minimum scores)*

	Pre-test			Post-test		
	Middle	Maximum	Minimum	Middle	Maximum	Minimum
Control group	18.67	30	6.75	21.16	30	7.89
Experimental group	18.71	30	7.01	21.09	30	7.85

Table 7. *Comparisons of averages by gender (CT test)*

	Pre-test average		Post-test average	
	Girls	Boys	Girls	Boys
Experimental group	16.65	19.35	20.73	22.25

3.2. Analysis of the CT test results

The AI test proposed by Estévez et al. (2019) assesses the degree to which students have learned about AI after the teaching experience. The results show differences in the content of the answers to open-ended questions between the pre-test and the post-test. In Question 1, they were asked "What is AI?" In the pre-test, the answers explain AI as referring to the intelligence of machines and robots, and in the post-test, the answers are more precise, such as "AI is a set of algorithms for learning." Thus, in question 6, which asked about "the dangers of AI", in the pre-test the students detailed their concerns about being subjugated by robots and machines. Whereas in the later phase, this perception of danger was reduced, and responses were oriented towards issues related to the impact of AI on privacy and personal security. Quantitative questions 2, 3, 4 and 5 were answered on a 5-point Likert scale. These questions and their response rates are presented in table 8.

Table 8. *Artificial Intelligence test results*

	Pre-test		Post-test	
AI Test questions (Estévez et al., 2019)	PA (%)	SD (%)	PA (%)	SD (%)
2-The level of technical knowledge required to understand AI is too high for the majority of the population.	50	17	15	73
3-If an algorithm can predict the outcome of a football match, it is very likely that it can predict the outbreak of World War III.	14	72	42	29
4-In less than 10 years, a Terminator-like AI will be developed that will threaten humanity.	62	34	19	62
5-As a user, the legal regulation of AI devices will affect my life.	62	4	85	7

PA: Partially agree; SD: Strongly Disagree. Indifferent responses were discarded.

The conclusion can be drawn that working on AI in a procedural and applied manner has helped students to deepen their knowledge of AI and understand the impact it can have on their lives, as well as to be more realistic and aware of what AI is, and above all what it is not, or false myths.

3.3. Analysis of the results of the pupils' digital literacy test

The ECODIES test can be used to estimate the overall digital competence of the adolescent population and also in the different areas in which the test is structured. However, our analysis has only focused on global digital competence, given the objectives and nature of our study. The result of the scores is presented on the basis of 100 points as a maximum possible. The results obtained are shown in table 9.

Table 9. *Digital competence results (ECODIES)*

		Middle	Maximum	Minimum	SD
Pre-test	Control	65.30	91.03	28.92	11.86
	Experimental	63.20	90.7	30.12	13.14
Post-test	Control	66.01	92.30	28.92	13.35
	Experimental	66.12	91.72	30.56	12.56

SD: Standard Deviation

A number of observations must be made in order to be able to properly interpret the results. The first is that the intervention is of relatively short duration, so that its effect on digital competence can hardly be very intense. The second issue is that pupils' digital competence is built through multiple interventions in different subject areas, but also at any other time outside school, so it is not very rigorous to believe that the improvement in digital competence is due to the effects of the intervention.

On these premises, a fairly high baseline mean is noted, which increases, albeit not significantly in the post-test. This improvement in mean digital competence is higher in the experimental group than in the control group.

3.4. Analysing the results of the student and teacher questionnaires

3.4.1. Analysis of the results of the teacher questionnaires

The analysis of the questionnaires provides us with two points of view, that of the Technology and Digitisation (TD) teacher who has more training and digital competence, as opposed to the Biology and Geology (BG) teacher for whom this was their first experience with ICT. The teaching staff recognise the importance of ICT as a source of educational resources for teaching, as well as dealing with individualisation and the diversity of classes. They also insist on the opportunity it represents for innovation and to move away from repetitive work and generate creative work in students.

On the impact of the learning project on pupils, the teachers involved point to increased motivation and performance of pupils, but also motivation for teachers:

> *BG Teacher: I thought it was amazing... Minerals are always one of the most difficult topics for students because they seem very far removed from their lives. I could see that they had fun and that it was hugely motivating for the experimental group. I also think that students have learned at a much deeper level because they see the applicability and connection between subjects.*
>
> *TD Teacher: I really liked it, for two reasons. Firstly, I think the students saw how the tools we work with can be applied, and secondly, because of the collaboration with other teachers, as they clearly saw the importance of ICT and how motivating it can be in the classroom.*

However, there are also aspects to be improved, the first being, obviously, the importance of planning joint work and, secondly, the improvement of digital teaching skills, especially in the Biology and Geology teacher:

> *TD Teacher: I liked it very much. It requires a lot of joint planning between the two teachers and a clear understanding of how the tools are used and what the objectives are. In my case, as a biology teacher, I had no idea about the tool, but it has helped me to learn about super-current things, such as AI.*
>
> *BG Teacher: One of the things that needs improvement is that I really need training in ICT, because I have no idea about it, and the other teacher had to help me with everything...*
>
> *Regarding the applicability of the project and the joint work between subjects, emphasis is placed on how this cross-curricular approach improves skills-based learning and the ability to learn how to learn:*
>
> *TD Teacher: I think it would be very useful. Interdisciplinary work is a pending subject in education in general. I believe that transversality helps children to see the link between the contents and, in short, to learn competences and above all to "learn to learn".*
>
> *BG Teacher: I could clearly see how important this is for the development of scientific competence. And, of course, it is also linked to digital competence.*

3.4.2. Analysis of the questionnaires of the students in the experimental group

As for the responses of the students who have participated in the joint BG and TD experience, all of them point to the motivating nature of the project and how it has helped them to better understand what AI is all about:

> *Questionnaire 71. I loved making an AI programme. To be honest, I didn't really understand what AI was all about... But it's actually really useful and you can do lots of things with it... I also found it easier to understand minerals, which I've always found really boring.*
>
> *Questionnaire 2. It's been cool... We've been working on AI, which is great. I already knew about CHATGPT... But it can be applied to so many aspects of everyday life... I think it's going to be everywhere.*

As for working together with other subjects, students report a higher level of learning and greater motivation:

Questionnaire 5. I really liked it... I would like to work on the other subjects like this because I think it's more practical and I understand it. It's better.

In summary, both the teachers involved and the students recognise greater motivation when AI is worked on jointly and applied in the subjects of BG and TD, as well as a better understanding of AI and how it can be applied in real life.

4. Discussion and conclusions

The teaching experience described in this study represents a step forward in educational innovation, integrating knowledge, people, methodologies and technologies. This has led to an improvement in professional teaching culture, as pointed out by Coll-Salvador et al. (2023), who emphasise the need for technologies in education to add practical value and improve educational processes. The results of the study show that:

(1) The teaching approach implemented in two subjects improved the experimental group's scores in critical thinking (CT), artificial intelligence (AI) and digital competence. Students reported having deepened their critical understanding of AI and the importance of collaboration in solving complex and innovative problems. This type of experience fosters deeper thinking in students, as Polanco et al. point out. (2021). The inclusion of AI made it possible to face real problems, showing that the motivation implicit in these real situations contributes to more meaningful and competent learning, as confirmed by previous studies (Ayuso del Puerto and Gutiérrez-Esteban, 2022; Flores-Rueda and Sánchez-Macías, 2021).

(2) Teachers noted that AI facilitates the personalisation of learning, promoting inclusive and equitable education, in line with the recommendations of UNESCO (2021) and the UN Sustainable Development Goals (SDGs) (2023). Both students and teachers recognise that the experience changed their perception of AI, seeing it as an opportunity rather than a threat, and developed entrepreneurial skills in students, which are essential in today's society (Sanabria and Cepeda, 2016; Palau et al., 2024).

(3) This research demonstrates that the use of AI tools in education enriches teaching-learning processes, empowering both students and teachers and preparing them for future challenges. There is a need to expand this research to other educational stages and subjects to ensure equitable access for all. Furthermore, there is a clear need to train teachers, both during initial training and in service, in the effective use of AI, through pedagogical support (Meneses and Fernández, 2020; Padilla et al., 2020).

In short, AI presents a major challenge in many areas, including education. Their knowledge in real contexts, as presented in this study, allows for a critical and reflexive approach to their use, contributing to a deeper understanding and demystification of their reality (UNESCO, 2023a). It also shows the importance of carrying out transversal experiences in the classroom with the development and application of educational innovations based on AI.

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