Gamified approaches to computational thinking in teacher training

Enfoques gamificados de pensamiento computacional en formación docente

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Abstract

This study explores the integration of computational thinking (CT) and gamification in teacher training. In the digital age, technology plays an essential role in all fields, including education. CT is already a fundamental skill in compulsory education, which implies a critical evolution in the contemporary educational landscape. Gamification has emerged as a powerful tool in education, revolutionising traditional teaching methods. By integrating game elements into the learning environment, gamification can increase student engagement and

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motivation, which are essential for effective learning. The study focused on the integration of gamification for CT promotion and training with 99 prospective teachers, using two types of gamification: shallow and deep gamification. Shallow gamification focuses on external components such as points, levels and badges, while deep gamification incorporates elements beyond the points that are considered meaningful to participants, such as personalised avatars, narratives, unexpected events and alternative activities. Results indicated improvements in self-perceived CT skills, particularly with deep gamification, but a decrease in the problem-solving dimension. In addition, higher motivation was observed in the shallow gamification group. These results have significant implications for teacher education. Overall, the integration of gamification into CT instruction represents a promising strategy for improving the training of future teachers in an increasingly digitised world. However, the implementation of gamification must be carefully considered to ensure that all CT skills are developed effectively. Ultimately, more research is needed to unravel the underlying causes of the results obtained and to explore the application of CT and gamification in various educational settings and levels.

Keywords: computational thinking, gamification, intrinsic motivation, extrinsic motivation, pre-service teachers, higher education.

Resumen

Este estudio aborda la integración del pensamiento computacional (PC) y la gamificación en la formación del profesorado. En la era digital, la tecnología desempeña un papel esencial en todos los ámbitos, incluida la educación. El PC constituye ya una habilidad fundamental en la educación obligatoria, lo que implica una evolución crítica en el panorama educativo contemporáneo. La gamificación, por su parte, ha surgido como una herramienta poderosa en la educación, revolucionando los métodos de enseñanza tradicionales. Al integrar elementos de juego en el entorno de aprendizaje, la gamificación puede aumentar el compromiso y la motivación de los estudiantes, fundamentales para un aprendizaje eficaz. El estudio se centró en la integración de la gamificación para la promoción y capacitación en PC con 99 futuros docentes, utilizando dos tipos de gamificación: superficial y profunda. La gamificación superficial se centra en componentes externos como puntos, niveles y medallas, mientras que la gamificación profunda incorpora elementos más allá de los puntos que se consideran significativos para los participantes, como avatares personalizados, narrativas, eventos inesperados y actividades alternativas. Los resultados indicaron mejoras en habilidades auto percibidas de PC, particularmente con gamificación profunda, pero una disminución en la dimensión de resolución de problemas. Además, se observó mayor motivación en el grupo con gamificación superficial. Estos resultados tienen implicaciones significativas para la formación

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del profesorado. En conjunto, la integración de la gamificación en la instrucción de PC representa una estrategia prometedora para mejorar la capacitación de futuros docentes en un mundo cada vez más digitalizado. Sin embargo, la implementación de la gamificación debe ser cuidadosamente estudiada para garantizar que todas las habilidades de PC se desarrollen eficazmente. En definitiva, se necesita más investigación para desentrañar las causas subyacentes de los resultados obtenidos y explorar la aplicación del PC y la gamificación en diversos entornos y niveles educativos.

Palabras clave: pensamiento computacional, gamificación, motivación intrínseca, motivación extrínseca, docentes en formación, educación superior.

Introduction

Today, in the digital era in which we are immersed, technology has an essential role in every field, including education. In this domain, computational thinking (CT) is acquiring a key role in recent years, receiving increasing interest of different countries which are including it as a necessary skill in compulsory education (Bocconi et al., 2022). This shift implies a critical evolution in the contemporary educational landscape, aligning it with the dynamic needs of the digital world.

Similarly, in this technology-driven era, gamification has emerged as a fundamental tool in education, revolutionising traditional teaching methods. By integrating gaming elements into the learning environment, gamification can increase student engagement and motivation. As educational institutions strive to prepare students for a rapidly changing world, gamification offers a dynamic and adaptive approach to teaching that resonates with today's digital natives. This has led to increased adoption of gamification strategies in educational settings around the world, as educators and policymakers recognise its potential in fostering critical skills and competencies in students (van Roy & Zaman, 2017).

The intersection between CT and games has already been explored both at pre-university levels (e.g., Madariaga et al., 2023) and in future teacher training (Tankiz & Atman Uslu, 2023). Moreover, the inclusion of CT and gamification into teacher education programmes is therefore essential to prepare educators to effectively navigate the contemporary educational landscape (Dong et al., 2023). By incorporating CT in teacher training, pre-service teachers can develop CT knowledge and pedagogical

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skills associated with teaching CT (Ottenbreit-Leftwich et al., 2021). At the same time, exposure to gamification can equip them with innovative strategies to engage and motivate their future students (Cózar-Gutiérrez & Sáez-López, 2016). As teachers are central to the learning experience, it is imperative that they are well versed in CT and gamification to foster a generation of technology literate, motivated and well-prepared learners. This integration into teacher training can ultimately contribute to a more adaptive and future-oriented education system.

Although there are existing studies which have used gamification as a method to teach CT, further research is necessary (Altaie & Jawawi, 2021). Because of that reason, this study aims to focus on the abilities developed by pre-service teachers using this type of thinking and gamification as part of the instruction. Within this study, we will examine the effect of a gamified CT instruction on pre-service teachers' abilities as well as their motivational outcomes. Concretely, we are especially interested in how shallow and deep gamification affect self-reported CT skills and intrinsic and extrinsic motivation.

Literature review

Computational thinking

The concept of CT emerged from the ideas of Seymour Papert (1980) who started talking about the relationship between programming and thinking abilities. However, it was years later when the concept became popular in education. Since then, different interpretations have attempted to reflect on the essence of this type of thinking. The most spread definition is the one of Wing (2006) who claims that CT involves: "solving problems, designing systems and understanding human behaviour by drawing on the fundamental concepts to computer science" (p.33). The author adds that this ability is essential for everyone, not only for scientists, comparing it with other abilities such as reading, writing or arithmetic. From this definition, two fundamental aspects can be drawn in the field of education according to a report published by INTEF (2017): the first aspect is that CT is independent of technology; the second is that this concept encompasses several different abilities to formulate problems and solutions. These two aspects will be discussed in

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the next sections. The last report published by the Joint Research Centre (Bocconi et al., 2022), also highlights the idea that CT is a fundamental skill that everybody should manage. Merino-Armero et al. (2021) see on CT an opportunity to change the role of pupils from simple consumers to creators of content, including all the skills that this latter role implies. For this reason, in recent years concern has increased in regards to the introduction of this concept in compulsory education.

There are multiple ways of including CT in Primary Education. In this study we consider the distinction between plugged-in activities and unplugged activities. On the one hand, plugged-in activities are those which normally use technological devices for the development of CT skills such as computers or robots. Inside this field, it has been shown that educational robotics can promote students' active participation in their learning process promoting meaningful learning and better academic achievement (Merino-Armero, 2021). Xia and Zhong (2018) also highlighted that educational robotics creates learning environments that promote interest and motivation reinforcing positive relationships between pupils. On the other hand, unplugged activities are used for teaching computational science without the need of using technological devices. This latter method is especially recommended in Primary Education as it has been demonstrated that it helps pupils to better comprehend the main concepts of CT. Different studies have shown that conducting blended approaches introducing unplugged activities before plugged-in ones can be an effective method for CT instruction (Del Olmo-Muñoz et al., 2020; Tsarava et al., 2019).

One of the areas which needs to be highlighted is programming, as it is closely related to CT. In the field of education, it was in the 1960s when the programming language called LOGO was developed, primarily aimed at helping children learn mathematical concepts (Papert, 1980). At present, there are several intuitive models that can be used to teach programming in Primary Education. Some examples are platforms that use block-based programming environments such as Scratch and Code.org, which allow users who have not programmed before to do so in an intuitive way, arranging blocks together. The present study also included Ozoblockly, a platform used for programming the movements and instructions that the Ozobot robot will then follow. The visual format that these platforms use is known as block-based programming, a method which different studies have shown to contribute to the improvement of CT skills (see e.g., Tsarava et al., 2019).

Various authors emphasise that CT encompasses diverse skills such as arithmetic, visual-spatial reasoning, creativity, critical thinking, systems thinking, and problem solving (e.g., Zapata-Ros, 2015). To assess these multifaceted skills, the Computational Thinking Scale (CTS) developed by Korkmaz et al. (2017) is the choice for the present study involving pre-service teachers. The CTS has not only undergone rigorous validity and reliability testing with university students, but also measures perceptions and attitudes towards CT (Román-González et al., 2019). This is crucial for teachers, as their perceptions and attitudes will determine how they will integrate CT into their future classrooms (Dong et al., 2023; Rich et al., 2020; Román-González et al., 2019).

The CT skills measured with the CTS are: creativity, algorithmic thinking, critical thinking, problem solving and cooperativity. For this reason, a better explanation of them is necessary to understand this study. Table I shows brief definitions of these skills in terms of CT.

Teachers' training

Considering all the advantages found in including CT in Primary Education, the importance of training teachers to introduce this ability in class has increased in recent years. However, although teachers can appreciate the benefits of incorporating thinking abilities such as CT into compulsory education, many are uncomfortable with technology

TABLE I. Abilities associated to CT

Creativity	Life-long ability necessary for finding different solutions for the same problem.
Algorithmic thinking	Skill required for finding the solution of a proposed problem turning daily life language into programming one.
Critical thinking	Use of cognitive skills to justify and assess a problem considering consistency and soundness.
Problem solving	Ability to overcome the obstacles that may arise when solving a problem.
Cooperativity	The ability to help each other in accordance with a common purpose.

Source: Korkmaz et al. (2017).

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use (Xia & Zhong, 2018), and the scarcity of trained teachers presents a current challenge in these stages (Bocconi et al., 2022). This challenge is even more important when their decisive role in changing education and schools in terms of the computational science field. Some studies have demonstrated that when teachers are involved in computational science courses, workshops or conferences, their confidence using technology and applying CT concepts increase (e.g., Rich et al., 2020). For this reason, pre-service teachers' and teachers' training is extremely necessary to give them enough tools so that they can implement it in class, taking advantage of the benefits that it brings.

Teacher training at university level should be the starting point for introducing CT in Primary Education, one of the main objectives being that teachers are capable of finding new ways of linking pedagogy with CT. To this end, Ottenbreit-Leftwich et al. (2021) propose that the challenge lies in strengthening teachers' skills to promote this learning. Above all, teachers are ultimately the ones who determine the use of technology in the classroom through their attitudes and thoughts among other things. Because of that, focusing on their training from the university stage is necessary (Bocconi, 2022).

Gamification

In order to integrate CT skills in Primary Education different educational methods have been proposed. Altaie and Jawawi (2021) suggested that one of the most powerful methods to learn CT is gamification. One of the main reasons to justify its implementation with CT is that it has been shown that its implementation in education increases motivation. Motivation plays a key role in educational settings as it can significantly influence learning outcomes. Self-Determination Theory (SDT) is a psychological framework that explains different types of motivation, focusing mainly on intrinsic and extrinsic motivation (Deci & Ryan, 1985).

According to SDT, intrinsic motivation refers to engaging in an activity for its inherent satisfaction or interest. In contrast, extrinsic motivation involves engaging in an activity for external rewards or to avoid negative consequences. According to Ryan and Deci (2000), SDT distinguishes between different regulations within extrinsic motivation, such as identified regulation and external regulation. Identified regulation is a form of extrinsic motivation in which individuals engage in an activity because they identify with its value and consider it personally important, becoming identified regulations (Guay et al., 2000). External regulation, also a form of extrinsic motivation, involves behaviour that is driven by external control, such as rewards or pressures, where internalisation does not occur. In addition to these, SDT also recognises amotivation as a lack of motivation or intention to act, as a result of a sense of lack of competence or a belief that one's actions will not lead to the desired outcome. Researchers have concluded that autonomous motivation, which encompasses intrinsic motivation and identified regulation, is the desired type of motivation for positive outcomes, whereas external regulation is considered the least desired type as it represents an unstable determinant of behaviour that can lead to amotivation when external regulations are removed (van Roy & Zaman, 2017). Understanding these facets of motivation through the lens of SDT can be critical in designing gamification strategies to improve student engagement and learning outcomes.

Moreover, it is demonstrated that gamification have positive effects not only on motivation, but also on cognitive and behavioural aspects in education (Sailer & Homner, 2020). Deterding et al. (2011) define gamification as the use of game elements in contexts that do not directly involve playing, to generate motivation and interest in participants. Other studies have gone one step further, arguing that two types of gamification exist: shallow and deep gamification (Gurjanow et al., 2019).

On the one hand, shallow gamification focuses on external components like the use of points, levels and badges, what is known by some authors as "pointification" (Huang et al., 2020). In general, shallow gamification makes use of pre-defined systems that provide these aspects. Moreover, this type of gamification is associated with extrinsic motivation as it just focuses on external aspects (Gurjanow et al., 2019). This is where the SDT becomes particularly relevant. Shallow gamification, with its predefined systems and external rewards, is closely related to the external regulation described in SDT, actions are influenced by external rewards or penalties (van Roy & Zaman, 2017).

On the other hand, deep gamification incorporates elements beyond points, which are meaningful for the participants (Mozelius, 2021). Some examples are: personalized avatars, narratives, unexpected events and alternative activities. These elements increase students'

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sense of autonomy like the capacity to choose the activities developed to promote their own learning and the identification of the implied participants with avatars chosen or designed by themselves. In this latter type of gamification, special attention is paid to create a narrative so that students feel identified in the teaching-learning process. Such elements of deep gamification resonate with intrinsic motivation, a central concept in SDT. When students are intrinsically motivated, they are driven by internal satisfaction and personal interest, which are fundamental for deep learning and better academic performance (Alsawaier, 2018).

Method

The problem in which this research is framed is the lack of knowledge about how to integrate CT in Primary Education as well as developing the skills which are related with it. Considering the possible problems that teachers may find when using it in class, either due to lack of training or not being comfortable with technology, the motivation of this study is to know the perception that pre-service teachers have about CT and its associated skills. In addition, the gamified instruction applied aims to discover the motivation that participants experience considering two types of gamification: shallow and deep.

Research questions

The study was guided by the following research questions:

- RQ1. Do pre-service teachers' self-perceived CT skills improve after the implementation of a gamified CT short instruction?
- RQ2. Do pre-service teachers' self-perceived CT skills differ depending on the type of gamification (deep or shallow) applied to a short CT instruction?
- RQ3. Do pre-service teachers' intrinsic and extrinsic motivation towards gamified CT instruction differ depending on the type of gamification (deep or shallow) applied?

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Design

Based on the main research questions of this study, a quasi-experimental design with two groups (control and experimental) was proposed. Both groups carried out a CT gamified instruction but they used different types of gamification. Specifically, the control group experienced shallow gamification for that instruction, whereas the experimental group experienced the same instruction by applying deep gamification to it. The differences between both groups are better explained in the procedure section.

Instruments

For this study, two validated existing questionnaires were used to measure pre-service teachers' attitudes towards CT and their motivation during the experience.

The first questionnaire (Korkmaz et al., 2017) measures different skills that have been demonstrated to be associated with CT which, are: creativity, algorithmic thinking, cooperativity, critical thinking and problem solving. The questionnaire consisted of 29 items that were answered by the participants on a scale from 1 to 5, being 1 "totally disagree" and 5 "totally agree". These items were classified into the different skills named before, following the original questionnaire guidelines. The test was administered before and after the gamified instruction to see the possible gains that pre-service teachers may have.

The second questionnaire (Guay et al., 2000) aims to measure participants' motivation towards the instruction. The authors developed this questionnaire from the stance of the SDT. The scale refers to the individual motivations that human beings experience when they are participating in a determined activity. Specifically, the authors distinguish four motivational constructs: intrinsic motivation, identified regulation, external regulation and amotivation. According to them, on the one hand, intrinsic motivation and identified regulation are said to be experienced when one behaviour is performed for self-choice reasons. On the other hand, external regulation is thought to be experienced because of

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external factors that are not directly related to the main activity. Finally, amotivation is defined as the feeling which is experienced when there is no motivation towards the activity itself, nor to the possible reward obtained.

This latter questionnaire was administered only after the gamified experience was applied to determine the motivation that pre-service teachers had towards the instruction. Consistent with this view, one of the main objectives of this questionnaire was to test the possible differences between both groups controlling the type of gamification as a variable. The questionnaire consisted of 16 items which were rated on a 7-point Likert scale being 1 "not at all in agreement" and 7 "completely in agreement".

Context

The present research was conducted with a total of 99 students from a Faculty of Education. All of whom were studying to obtain the Primary Education Degree. The proposal was specifically developed on the subject of History and Social Science in the University of Castilla-La Mancha. The control and the experimental group consisted of 49 and 50 students respectively. Both groups were in the second course of the degree on Primary Education teaching. The proposal was developed during weekly hours that are normally booked for seminars. At the beginning of the intervention, in response to an explicit inquiry, the students expressed that they had no knowledge of CT and had not worked on it in any previous course. In Table II there is a representation of the participants of this research:

TABLE II. Participants

Group	Students	Gender
Control	49	Males: 18; Females: 31
Experimental	50	Males: 11; Females: 39

Source: Compiled by the authors.

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Procedure

For the instruction design, as it has been explained previously, gamification was used to involve students and to provide the sessions with a common thread that would encourage the implementation of CT in Primary Education subjects. In this case, the instruction was held in the subject of Social Science: History and Didactics, in the second grade of the Degree on Primary Education. All the activities were designed around this subject to get as close as possible to the interests of the participants, but without modifying the contents of CT.

Firstly, concerning the instruction it is necessary to explain the differences between both groups in terms of gamification. Regarding the control group (in which shallow gamification was applied), the gamification elements were, mainly, points and leader boards. Students from this group also used avatars from historical characters to represent themselves that were randomly assigned to each participant. The experimental group, however, carried out an instruction using deep gamification. Therefore, in addition to the points and leader boards, they used avatars created by themselves and the gamification had a narrative related to History that tried to link the whole experience together. This way, the activities developed were not perceived isolated as in the control group, but they were seen as a group of activities that had a specific goal. The "MyClassGame" platform was used to track the progress of both groups. This platform allows students and teachers to identify themselves with a character, reflecting the points and advancements that they carry out. Figure I shows an illustration of this platform with the students' names anonymized.

Regarding the gamified instruction, it was composed of four sixty-minute sessions in which a variety of unplugged and plugged-in activities were presented to the participants. The method followed was based on a blended perspective: two sessions consisted of unplugged activities and two sessions consisted of plugged-in activities, which were the same for both groups. The only difference between control and experimental group lies in the gamification elements mentioned before.

Unplugged activities were selected from the website Code.org and adapted to our specific research objectives. This website counts with a wide variety of activities that can be used at different educational levels to learn CT. Because of it, as we were working with pre-service teachers,

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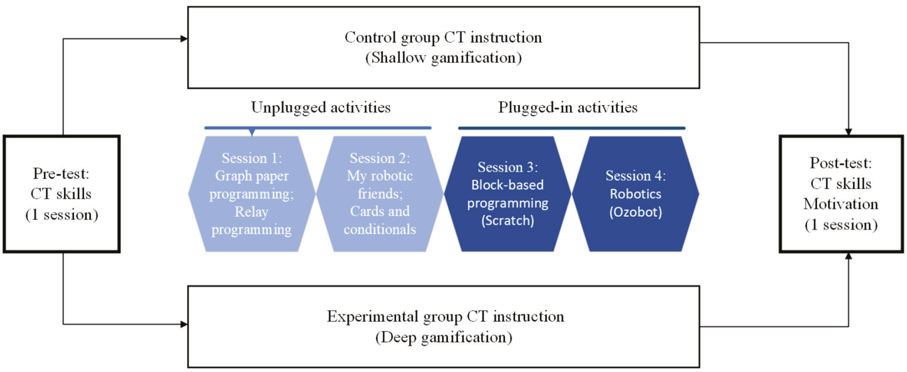
we wanted them to have real experiences that they could apply in their future classes. Regarding plugged-in activities, they were planned using the platforms Scratch and OzoBlockly. This last one was introduced to work with robotics.

Figure II provides a detailed overview of the structured sessions, covering both the questionnaires and the diverse range of activities that constituted the instruction for both experimental conditions. It is

FIGURE I. MyClassGame platform

Source: Compiled by the authors.

FIGURE II. Study design and session procedure



Source: Compiled by the authors.

necessary to mention that in the post-test phase, both questionnaires were administered in the same session, with a brief pause between them to minimize participant fatigue. The layout and progression of these sessions were influenced by existing research (Ottenbreit-Leftwich et al., 2021; Tsarava et al., 2019), which advocates the integration of unplugged activities as precursors, plugged activities and simulation or fieldwork with robotics, as an effective approach in CT instruction.

Sessions

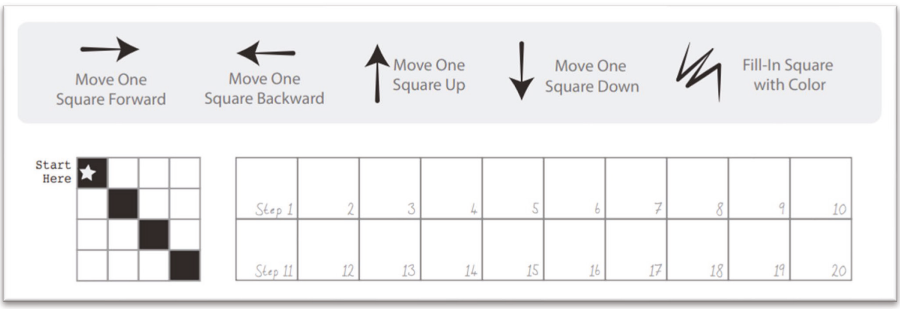
Within this section a detailed explanation of the sessions that were developed during the gamified instruction on CT in both groups is shown.

The first unplugged session consisted of two activities whose objective was to introduce pre-service teachers to programming concepts. The first activity was called "Graph Paper Programming" and it was adapted from the website Code.org. The aim of this activity was to work on basic concepts such as sequences and algorithms. The abilities developed with this activity were problem solving and algorithmic and critical thinking and the objectives pursued were:

- To organise sequences in a logical order.
- To communicate ideas through codes and symbols.

In this activity participants had to write down individually the necessary instructions that a programme would theoretically follow to colour a grid. Figure III shows an example of this activity.

FIGURE III. Graph paper programming example



Source: Code.org (2018).

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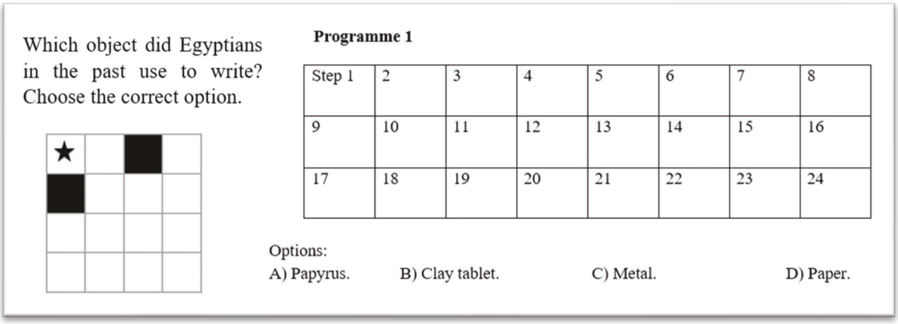
The second activity was called “Relay Programming”. This activity followed the same dynamics as the previous one but in this case, it was necessary to work in teams so that we introduced participants to cooperativity skills. Participants were divided into groups of five and organised in a queue up relay-style. On one side of the room there was a queue of participants and on the other side a grid paper like the one which is shown in Figure IV. In turns, each participant needed to set a single instruction, run back and tag the next person in line so that they could write the following instruction. If a participant noticed that one of their partner’s instructions was wrong, he or she would cross it out and write a new one. We wanted participants to work on the concept of “debugging” which means identifying and correcting possible mistakes that may arise in programming. The objectives pursued of this activity were:

- Define ideas using codes and symbols.
- Become familiar with the concept “debugging” by checking the work done by their teammates.

The abilities developed with this activity were mainly cooperativity and critical thinking. To link the activity with the History and Social Science subject, the participants needed to answer a few questions that were proposed, as can be seen in Figure IV. In this way, the colouring option was replaced by the correct letter which stands for the answer expressed below. Figure IV shows an example in which two answers were correct.

The second unplugged session consisted of two activities. The first activity was called “My robotic friends” and it was also adapted from Code.

FIGURE IV. Relay Programming

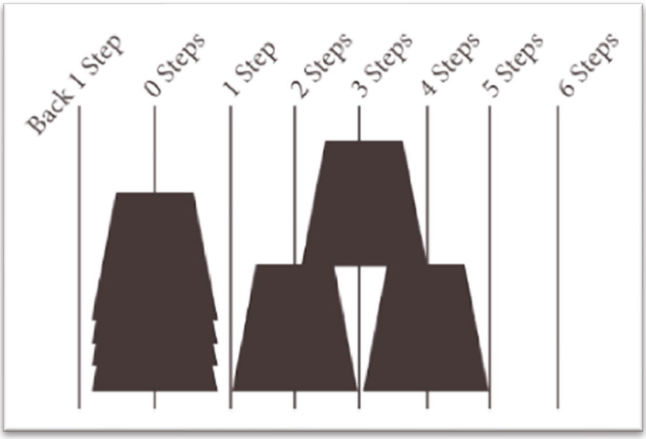


Source: Adapted from Code.org (2018).

org. During this activity the participants needed to give the necessary instructions (turning the steps into programming language) to build up a tower of cups. This tower was built following a template which was provided by the researchers (Figure V).

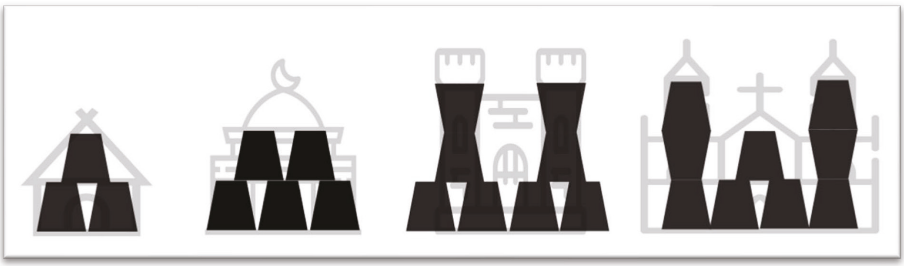
Similar to the first session we continued working with simple algorithms. The activity was developed in pairs: one student was assigned the writing of the instructions while the other carried out those instructions as if he/she was an "imaginary robot". Figure VI shows ideas for cup constructions related to History that were provided to the students.

FIGURE V. Tower of cups template example



Source: Code.org (2018).

FIGURE VI. Ideas for cup constructions related to History



Source: Compiled by the authors.

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Regarding the abilities associated with CT, this activity developed critical thinking and cooperative work. The objectives pursued were:

- To trace a sequence of steps as a coded program.
- To recognise and correct possible errors in the instructions of a sequence (internalising the concept of debugging).

The second activity of this second session aimed to work the concept of "conditionals" in programming. For that purpose, a card game related with history concepts was designed. The participants needed to create their own rules with the cards given. However, the instruction should be written using blocks programming language. The objectives that this activity followed were:

- Define the requirements that a programme must meet to be executed or not.
- Determine whether a conditional is fulfilled according to the requirements given.

Within this activity the abilities cooperativity and critical thinking were developed. Figure VII shows an example extract of the instructions that were given by the participants for a card game:

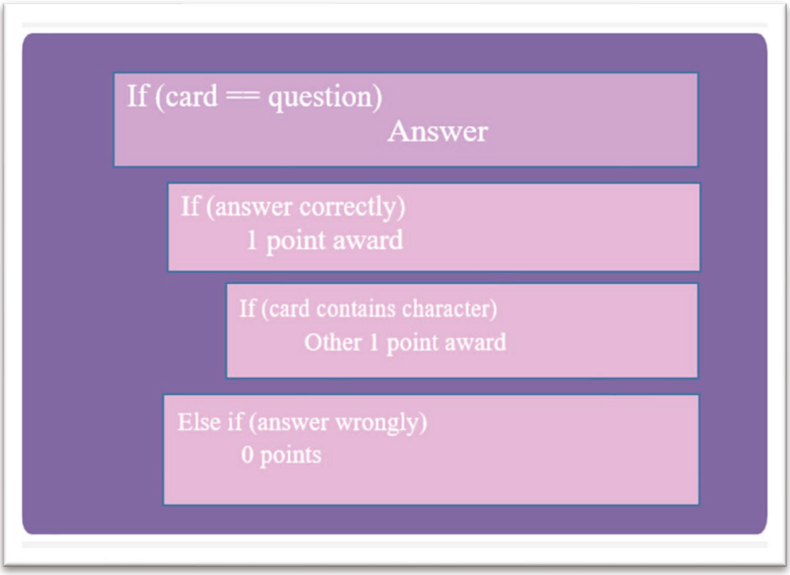
In the third session plugged-in activities were introduced. For that purpose, the educational platform Scratch was used. This platform allows programming by blocks to create activities and games. Thus, the participants needed to create their own programmes thinking about how they would develop this activity in the subject of History and Social Science. The abilities associated with CT that are developed with this activity are mainly creativity and critical thinking. The objectives of this activity were:

- To transfer the knowledge acquired in the unplugged activities to the plugged-in ones.
- To work on conditionals in programming.
- To be able to write a programme, and in case of making mistakes, to know how to correct them.

An example of these programmes is presented in Figure VIII.

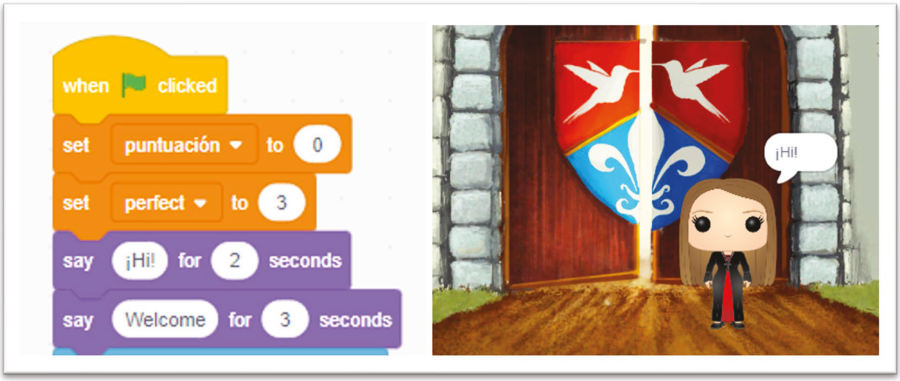
In the fourth session, following the line of plugged-in activities, educational robotics was introduced. In this case we worked with

FIGURE VII. Conditionals example



Source: Compiled by the authors.

FIGURE VIII. Scratch programme example



Source: Scratch (2023).

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Ozobot, a robot the size of an eyeball that can be used as an introduction to programming in educational environments. This robot is programmed through block-based programming in the website "Ozoblockly". Once the instructions are made, the robot needs to be loaded with them and it will be ready to execute the programme. Concretely, we used its "follow-lines" mode. Within this session we provided participants with a board that contained some objects and inventors' names. Using the board presented, the students needed to program the robot in groups (using Ozoblockly platform) to link the two elements that were related together. The abilities associated with this session were cooperativity, creativity and problem solving. The objectives pursued with this activity were:

- To program by blocks to make the "Ozobot" follow the instructions.
- To be able to correct mistakes in case the "Ozobot" does not follow the instructions correctly.
- To encourage creativity by adding different options and trying out alternatives.

Results

To answer the objectives of this study, two validated existing questionnaires were used: one questionnaire was aimed to evaluate pre-service teachers' skills associated with CT (Korkmaz et al., 2017) and the other one was held to measure participants' intrinsic and extrinsic motivation (Guay et al., 2000) towards the gamification experience implemented. Cronbach alpha reliability coefficient was used to evaluate the internal reliability of the questionnaires. The scores for the CT instrument by dimensions in the pre-test and post-test, respectively, were: creativity (α_{pre}=.72; α_{pos}=.79), algorithmic thinking (α_{pre}=.80; α_{pos}=.86), cooperativity (α_{pre}=.91; α_{pos}=.91), critical thinking (α_{pre}=.75; α_{pos}=.77), and problem solving (α_{pre}=.75; α_{pos}=.73). In the case of motivation, the alphas for each dimension were: intrinsic motivation (α=.86), identified regulation (α=.76), external regulation (α=.80), and amotivation (α=.86). In all cases, the values are within intervals considered respectable (.70-.80) or very good (.80-.90) (DeVellis & Thorpe, 2022).

Following the guidelines of the original questionnaire by Korkmaz et al. (2017), to analyse the results, we considered the different dimensions in which it is divided: creativity, algorithmic thinking, cooperativity, critical thinking and problem solving. Table III shows the results obtained broken into these dimensions, considering pre-test and post-test data of both groups separately and together (Total).

In regards to self-perceived CT skills, an independent samples t-test was performed on pre-test scores to ensure that the control and experimental groups were comparable before the intervention. The test revealed no statistically significant differences ($t(73) = -0.54$, $p = 0.5940$, $d = -0.12$), indicating that both groups had similar baseline levels.

TABLE III. Pre-service teachers self-perceived CT skills

Dimension	*n*	Group	Pre-test	Post-test	Comparison
Creativity	42	Control	4.02 (0.39)	4.09 (0.44)	***t***(41)=1.23, ***p*** = .2258, ***d*** = 0.19
	39	Exp.	4.09 (0.45)	4.11 (0.48)	***t***(38)=0.49, ***p*** = .6302, ***d*** = 0.08
	81	Total	4.05 (0.42)	4.10 (0.46)	***t***(80)=1.24, ***p*** = .2175, ***d*** = 0.14
Algorithmic thinking	42	Control	3.00 (0.74)	3.13 (0.74)	***t***(41)=1.45, ***p*** = .1537, ***d*** = 0.22
	39	Exp.	2.78 (0.63)	3.00 (0.81)	***t***(38)=2.78, ***p*** = .0085, ***d*** = 0.45
	81	Total	2.90 (0.70)	3.06 (0.77)	***t***(80)=2.91, ***p*** = .0047, ***d*** = 0.32
Cooperativity	42	Control	4.15 (0.80)	4.33 (0.69)	***t***(41)=1.90, ***p*** = .0639, ***d*** = 0.29
	39	Exp.	4.38 (0.65)	4.38 (0.62)	***t***(38)=0.08, ***p*** = .9364, ***d*** = 0.13
	81	Total	4.26 (0.74)	4.36 (0.65)	***t***(80)=1.38, ***p*** = .1715, ***d*** = 0.15
Critical thinking	42	Control	3.64 (0.54)	3.79 (0.61)	***t***(41)=1.60, ***p*** = .1170, ***d*** = 0.25
	39	Exp.	3.47 (0.62)	3.67 (0.63)	***t***(38)=3.26, ***p*** = .0024, ***d*** = 0.52
	81	Total	3.56 (0.58)	3.73 (0.62)	***t***(80)=3.14, ***p*** = .0024, ***d*** = 0.35
Problem solving	42	Control	2.27 (0.58)	2.07 (0.48)	***t***(41)=2.51, ***p*** = .0163, ***d*** = -0.39
	39	Exp.	2.28 (0.56)	2.25 (0.58)	***t***(38)=0.49, ***p*** = .6272, ***d*** = -0.08
	81	Total	2.28 (0.57)	2.16 (0.53)	***t***(80)=2.27, ***p*** = .0259, ***d*** = 0.25
Total	42	Control	3.38 (0.26)	3.42 (0.26)	***t***(41)=1.07, ***p*** = .2909, ***d*** = 0,17
	39	Exp.	3.34 (0.32)	3.43 (0.33)	***t***(38)=2.71, ***p*** = .0100, ***d*** = 0,43
	81	Total	3.36 (0.29)	3.42 (0.29)	***t***(80)=2.38, ***p*** = .0198, ***d*** = 0.26

Source: Compiled by the authors.

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While the intervention did not lead to statistically significant improvements in all individual dimensions, the aggregate analysis of the total scores of self-perceived CT skills indicates a statistically significant improvement in the participants as a whole across the combined dimensions, with a small effect size according to Cohen (1988). This suggests a generalized improvement in the broader CT construct measured by the instrument, regardless of the experimental condition. When examining the overall results considering the experimental conditions, only the experimental group demonstrated a statistically significant improvement in the post-test total scores, with a small-intermediate effect size according to Cohen (1988), suggesting that the effect of the intervention is noticeable and potentially meaningful for this group.

Shifting focus to a more granular analysis of the results on the different dimensions, irrespective of the experimental condition, the participants collectively showed significant gains in the algorithmic thinking and critical thinking dimensions. In contrast, there was a significant decline in the problem-solving dimension. When examining the results by experimental condition, the most pronounced gains were observed in algorithmic and critical thinking for the experimental group, with small-intermediate and intermediate effect sizes, respectively, according to Cohen (1988). An intriguing exception to this trend of improvement was the dimension of problem-solving skills, where a significant decrease in scores was observed for the control group.

In addition to self-perceived CT skills, we measured the type of motivation that the participants experienced. To do so, the questionnaire validated in Guay et al. (2000) was used. As explained in the instruments section, this questionnaire distinguishes different motivational constructs: intrinsic motivation and identified regulation (which are related to participants self-choice), external regulation (in which participants perform the activities to obtain a reward) and amotivation (involving neither intrinsic nor extrinsic motivation). Table IV shows the results obtained distinguishing these constructs considering both, experimental and control group.

From the standpoint of descriptive analysis, the results indicate favourable motivational outcomes across all dimensions for both groups, particularly noteworthy on a 1 to 7 scale, where external regulation is the closest to a neutral midpoint (value 4). This is significant, especially since intrinsic motivation and identified regulation are esteemed as the most

TABLE IV. Motivation results

Motivation type	Experimental group	Control group	Comparison
Intrinsic motivation	5.63 (1.10)	6.06 (0.74)	***t***(67.3)=-2.09, ***p*** = .0408, ***d*** = -0.46
Identified regulation	5.14 (1.00)	5.35 (1.02)	***t***(83)=-0.95, ***p*** = -.3440, ***d*** = -0.21
External regulation	3.39 (1.21)	2.99 (1.25)	***t***(83)=1.52, ***p*** = .1330, ***d*** = 0.33
Amotivation	2.16 (1.13)	1.58 (0.52)	***t***(53.2)=2.94, ***p*** = .0048, ***d*** = 0.65

Source: Compiled by the authors.

advantageous forms of motivation. Considering the differences between experimental conditions, it can be seen that the control group obtained higher results in intrinsic motivation than the experimental group. Considering that external regulation and amotivation are areas in which lower scores are desired due to their negative implications, the control group also excelled, showing significant lower levels of amotivation compared to the experimental group. According to Cohen (1988), the effect sizes indicate small differences for identified and external regulations, small-intermediate differences for intrinsic motivation and intermediate differences for amotivation.

Discussion

This study aimed to explore the impact of gamified CT teaching on the skills and motivation (intrinsic and extrinsic) of CT pre-service teachers through the lens of three research questions. In doing so, differences in outcomes attributed to the use of deep gamification techniques for the experimental group and shallow gamification techniques for the control group were critically examined.

Regarding the first research question (RQ1), which asked whether pre-service teachers' self-perceived CT skills would improve after a brief gamified CT instruction, the results indicated a positive trend in the overall score of self-perceived CT skills among the participants, irrespective of the experimental condition. This is in line with the results of previous studies (Del Olmo-Muñoz et al., 2023), but at a different educational level. When dissecting the results according to the different dimensions of self-

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perceived CT skills, a lack of uniformity emerges: while there is evident progress in algorithmic thinking and critical thinking, perceptions related to problem solving have experienced a decline. This variability suggests several underlying factors at play and opens new avenues for further research. In order to properly interpret these results, it is important to note that this study did not include a control group without any form of gamification, so improvements cannot be attributed solely to the gamified elements of instruction.

Moving on to the second research question (RQ2), which sought to investigate the differences in self-perceived CT skills depending on the type of gamification implemented, the results showed that the experimental group, subjected to deep gamification techniques, showed statistically significant improvements in self-perceived CT skills overall. Improvements were most prominent in the dimensions of algorithmic thinking and critical thinking. These results are consistent with previous research claiming that immersive gamified experiences can foster engagement and learning outcomes (Altaie & Jawawi, 2021; Sailer & Homner, 2020; van Roy & Zaman, 2017). However, there is a notable exception in the problem-solving dimension for the control group. Contrary to expectations, this group exhibited a decrease in their results after the implementation of the gamified CT instruction. This is unexpected as other studies have shown improvements in problem solving following CT instruction (e.g., Çakır et al., 2021). One of the possible reasons of this fact, could be the fact that the shallow gamification techniques used in the control group may not have been sufficiently engaging or motivating for participants to become deeply attached to problem solving. Deep gamification, with its immersive elements, might be more conducive to developing a problem-solving mindset by stimulating sustained critical thinking and engagement (Alsawaier, 2018).

Considering the third research question (RQ3) related to motivation, the findings from the results section reveal that the control group, which was exposed to shallow gamification, scored higher on intrinsic motivation, a key type of motivation linked to positive outcomes. Although the difference in identified regulation between groups was not statistically significant, it is noteworthy to mention that there was a small effect size that leaned in favour of the control group too. Conversely, the experimental group, engaged in deep gamification, showed higher scores in external regulation. Although these differences did not reach statistical significance, there was a small effect size observed, slightly favouring the experimental group. This would have negative implications, being external motivation not desired as it can lead to amotivation when external regulations are removed (van Roy & Zaman, 2017). In fact, the experimental group obtained a higher value also in terms of amotivation. All of these results expressed a contrast with literature findings, in which some authors have demonstrated a correlation between on the one hand, intrinsic motivation and deep gamification and on the other hand, extrinsic motivation and shallow gamification (Gurjanow et al., 2019; Mozelius et al., 2021). These unexpected results could be due to a confluence of factors. One possible explanation could be the length of the gamified experience. Being implemented across only four sessions, deep gamification may not have worked so well in the short term (Alsawaier, 2018). This suggests that more extended engagement with CT instruction might be necessary for substantial impact on motivation.

In addition, the context and environment in which the study was conducted might have interacted with the gamification strategies, leading to divergent results from the literature. Taking these aspects into account, it is essential to interpret the results with caution and to consider further research to unravel the underlying causes of such results. Because of that, as some authors like Altaie and Jawawi (2021) have suggested, we adhere to the demand for more research in this field to prove not only the integration of gamification into CT, but also the correlation between the type of motivation that participants experience considering shallow and deep gamification.

Limitations and future research

This study, while providing insights into the integration of CT and gamification, has certain limitations that warrant consideration for future research. Firstly, the sample size was modest, with 99 participants from the same age group. To increase the generalisability of the results, future research should consider using a larger and more diverse sample, considering demographic variables such as age, gender and educational level, as recommended by Dong et al. (2023).

Another noticeable limitation is the duration of the gamified instruction, which comprised only four sessions. Although these sessions were designed to be representative of core CT teaching methods, including unplugged and plugged-in activities and robotics, the brevity of the intervention might have

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impeded participants' ability to fully engage and assimilate the content. In addition, the short time frame may not have been conducive for the deep gamification approach to manifest its alleged effects on intrinsic motivation. A design with a longer duration and more comprehensive gamification elements should allow for a more in-depth investigation of the effectiveness of different gamification strategies. It is also important to analyse the application of gamification methodologies. Although deep gamification was structured with a cohesive narrative, it did not produce the intended impact on intrinsic motivation. This calls for more complex designs, which could include different levels of gamification, to unravel the nuances of the relationship between different types of gamification and motivation.

Furthermore, the transferability of the results to different contexts is vital. Exploring the application of CT and gamification in diverse educational settings, such as different universities or K-12 schools, can elucidate the adaptability and effectiveness of these approaches across diverse educational landscapes. For example, Del Olmo-Muñoz et al. (2023) provide an example of the application of gamified CT instruction in primary school. This article highlights how gamified approaches can foster engagement and computational thinking skills among young learners, highlighting the potential for these approaches to be adapted and applied across diverse age groups and educational settings. In light of this, education practitioners and policy makers should consider integrating gamified CT teaching tailored to the specific needs and contexts of their learners.

Finally, the interdisciplinarity of CT has been suggested in this study, with its application demonstrated in subjects such as History and Social Sciences. However, it's noteworthy that no significant improvement was observed in dimensions such as creativity and problem solving, which warrants careful consideration. Future studies could design interventions that integrate CT into a wider range of subjects in Primary Education, exploring how gamification can be effectively employed in these contexts to foster holistic development of CT skills and competences.

Conclusion and implications of the study

Technology has acquired great importance in the last few years, especially in terms of promoting abilities such as CT. Within this study we have addressed the relevance of introducing CT in pre-service teachers

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training at university. In line with some emerging studies (Altaie & Jawawi, 2021; Del Olmo-Muñoz et al., 2023), this study has demonstrated that blending CT and gamification is a good model to do so, as it can motivate participants and offer them a different vision to incorporate it in their future classrooms.

Analysing the results obtained, it can be noted that, after applying a CT instruction, pre-service teachers improved their self-perceived CT skills considering the different areas that Korkmaz et al. (2017) suggested such as critical thinking and algorithmic thinking. However, in this study it was appreciated that there was an exception in the problem-solving skill, where the results decreased after developing the gamified CT instruction, instead of increasing as was expected. Moreover, it has been demonstrated that it is possible to introduce CT concepts in diverse subjects, in this case History and Social Science. Regarding gamification, the results have shown that there is no clear relationship between deep gamification and intrinsic motivation on the one hand, and shallow gamification and extrinsic motivation on the other hand. Nevertheless, it seems that presenting pre-service teachers CT activities together with a gamification methodology had a positive effect in motivational aspects in both groups, irrespective of the type of gamification applied. Thus, we encourage future researchers to explore combinations of CT and gamification to provide pre-service teachers with the necessary background to teach CT in primary education, as it has been shown to be an essential skill that helps learners in different aspects of their lives. Education depends to a large extent on teachers. For this reason, investing in initial teacher training is a key point for introducing CT at primary education schools.

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