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DEVELOPMENT OF COMPUTATIONAL THINKING USING BOARD GAMES:

A SYSTEMATIC LITERATURE REVIEW BASED ON EMPIRICAL STUDIES

DESARROLLO DEL PENSAMIENTO COMPUTACIONAL MEDIANTE JUEGOS DE MESA:

UNA REVISIÓN SISTEMÁTICA DE LA LITERATURA BASADA EN ESTUDIOS EMPÍRICOS

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ABSTRACT

Computational Thinking (CT) has been highlighted as a key competence of the 21st century. The literature has pointed to the use of unplugged activities, including board games (BG), as a strategy to promote the development of Computational Thinking. Recently, new modern board games (MBG), referred to as Eurogames, have aroused the interest of researchers who have underlined their unique design and mechanics. To investigate the impact of the use of MBG on CT development, a systematic literature review (SLR) was structured using the PRISMA protocol as a reference. The focus was centred on the analysis of empirical studies based on the use of board games in school settings to promote CT skills. This paper opens with the presentation of several essential concepts, among which CT and Eurogames are included, followed by the results of the SLR, focusing on the analysed articles, the theoretical frameworks supporting the studies, the research contexts and methods, the data collection instruments and the results reported by the authors. Out of 85 articles, 11 studies published between 2011 and 2021 were analysed. The results suggest that game mechanics, typical of Eurogames, reveal the potential to promote CT. However, the use of these resources requires further exploration.

RESUMEN

El Pensamiento Computacional (PC) ha sido destacado como una competencia clave del siglo XXI. La literatura ha señalado el uso de actividades desconectadas, incluidos los juegos de mesa (JM), como estrategia para promover el desarrollo del Pensamiento Computacional. Recientemente, los nuevos juegos de mesa modernos (JMM), denominados eurojuegos, han despertado el interés de los investigadores, que han destacado su diseño y mecánica únicos. Para investigar el impacto del uso de JMM en el desarrollo del PC, se estructuró una revisión sistemática de la literatura (RSL) utilizando el protocolo PRISMA como referencia. El enfoque se centró en el análisis de estudios empíricos basados en el uso de juegos de mesa en entornos escolares para promover las habilidades de PC. Este artículo se abre con la presentación de varios conceptos esenciales, entre los que se incluyen el PC y los eurojuegos, y a continuación se presentan los resultados de la RSL, centrándose en los artículos analizados, los marcos teóricos que sustentan los estudios, los contextos y métodos de investigación, los instrumentos de recogida de datos y los resultados comunicados por los autores. De los 85 artículos, se analizaron 11 estudios publicados entre 2011 y 2021. Los resultados sugieren que las mecánicas de juego, típicas de los eurojuegos, revelan el potencial para promover el PC. Sin embargo, el uso de estos recursos requiere una mayor exploración.

KEYWORDS

Unplugged Activities; Eurogames; Tabletop Games; Board Games; Computational Thinking; Systematic Literature Review.

PALABRAS CLAVE

Actividades Desconectadas; Eurojuegos; Juegos de Mesa; Juegos de Tablero; Pensamiento Computacional; Revisión Sistemática de la Literatura.

1. INTRODUCTION

Computational Thinking, taken as a skill that may enable the development of a generic solution to a problem, has been acknowledged as an indispensable skill for human beings in the 21st century (Wing, 2006). By means of various cognitive processes, it draws on creativity, abstraction from the world, the identification of variables and recognition of patterns to break down a problem into several parts, thus deriving a solution of an essentially algorithmic nature (Martins *et al.*, 2020; Wing, 2008). Computational Thinking is, in itself, a strong cognitive component, encompassing several concepts and distinct computing-related reasoning, but it is also useful in several other real-life domains and contexts. Research in this field has focused mainly on the integration of Computational Thinking in STEM Education, its assessment and the standardisation of the concept and respective skills (Tekdal, 2021). To this end, three types of pedagogical approaches are recognised as fundamental to the development of computational thinking: programming, educational robotics and unplugged activities, which include board games (Menon *et al.*, 2019). In the last few years, the use of board games has made it possible to address different types of learning, especially at the level of CT. (Menon *et al.*, 2019). In fact, there is currently a growing trend towards the use of new types of board games known for their unique game mechanics: Eurogames (Woods, 2019). Defined as modern board games, Eurogames are the outcome of a cultural and historical context, originating in Germany in the 1960s and spreading significantly throughout the world. Their characteristics have influenced the current market and are currently a reference in board game design. Generally speaking, Eurogames or modern board games are recognised as accessible games, favouring game mechanics, facilitating indirect conflict, being devoid of the luck factor, capable of providing thematic and immersive game experiences, with predetermined times and usually with high quality presentation and components (Woods, 2019). In view of the above, this study aimed to investigate the use of modern European-style board games in the development of Computational Thinking in school children. To this end, a literature review process was structured, analysing a set of published, peer-reviewed empirical studies on the development of Computational Thinking skills through board games.

1.1. FRAMEWORK

1.1.1 Definition of Computational Thinking

The conviction that programming should be taught and learned from an early age date back to the 1960s, namely to the studies of Alan Perlis, whose reflections pointed to the inclusion of programming activities during the course of the teaching process. The author defended programming as an important step towards the understanding of Alan Turing's Theory of Computation, since although the current technological revolution had already been envisaged, his automated processes using machines were regarded as an innovative means of exploring knowledge (Guzdial, 2008).

The constructionist work of Papert (1980) and his LOGO project embodied the first ideas of Alan Perlis, through the creation of a simple programming language accessible to everyone. From then on, the idea of computing began to spread across and arouse the interest of the whole scientific community (Grover & Pea, 2013), prompting Wing (2006) to present the CT concept for the first time. Describing it as a key competence that everyone should develop in the 21st century, the author refuted the stereotypical idea of a skill that was exclusive to computer science engineers and scientists. In Wing's view (2006), CT involves the ability to solve problems, create systems and understand human behaviour, based on computing strategies. Through various procedural phases, Computational Thinking was thus defined as a human skill of an intellectual and creative nature, whose abstraction from the world enabled the decomposition of a problem through the identification of variables and the recognition of patterns, thereby leading to an algorithmic solution (Martins *et al.*, 2020; Wing, 2006; Wing, 2008).

At a later stage, Wing referred to particular aspects that have attracted the attention of research: 1) CT alludes to the formation of a specific concept and not to the procedural development of a programming language or the act of programming; 2) it is a process that is interconnected with logical reasoning, thus allowing for the greater flexibility of cognitive structures; 3) it is an inherent way of thinking for human beings which enables problem solving; 4) it is a combination of the cognitive processes associated with mathematics and engineering, conceiving a broader, more comprehensive and complete way of thinking; 5) it is a finished product of thought structures, which contributes not only to solve real-world problems and manage everyday behaviour, but also to communicate and interact with other people; 6) it is an essential and basic skill of everyday life, not ideological speculation (Wing, 2008).

In recent years, these arguments have given rise to considerable research around the concept of CT, based on this new perspective of the relationship between man and machine. Several authors have presented complementary definitions, describing CT as a cognitive process that allows for the formulation of problems and the identification of solutions tailored to different contexts and represented step-by-step through algorithms (Aho, 2012; Shute *et al.*, 2017). In line with Wing (2006; 2008), Grover and Pea (2013) added that CT invokes heuristic reasoning, abstraction and the generalisation of ideas automated by people and/or machines which, when transformed, would give rise to output information, i.e., data or objects. However, CT should not be confused with programming, since the latter concept would merely be a part of the former.

Thus, while CT falls within the dimension of ideas, since it is a thought realised at several levels of abstraction, programming allows for the communication of ideas through a machine (2006; 2008). The concept of abstraction has therefore emerged at the top of the taxonomy associated with CT. A precise abstraction process leads to correct and efficient solutions, anchored on three pillars: 1) succinct, assertive and unambiguous coding; 2) reduction of task complexity through decomposition into smaller parts; 3) modelling and identification of aspects relevant to the problem and possible correlations (Wing, 2011). Although CT is not understood as a typically mechanical skill, it should still be able to propose automated routines, thus simplifying daily activities (Grover & Pea, 2013; Wing, 2006).

The origin of automation as a concept is rather old and dates back to the first records of man on earth. The construction of pyramids, the structuring of ancient civilisations or the strategic organisation of armies are just a few examples that point to the human being as a computer machine, framed in space and time (Martins *et al.*, 2020). Regarding the CT structure, several authors have invested in a detailed study of the concept. Lee et. al. (2011) mention a progressive model referred to as "Use-Modify-Create". The authors state that: 1) in the "Use" phase, the students are consumers who take possession of and experiment with the ideas and creations of others; 2) in the "Modify" phase, the initial ideas are refined; 3) in the "Create" phase, the students develop their own ideas, using abstraction, automation and analysis. However, Brennan and Resnick (2012), based on Papert (1993), argue that there are three dimensions in CT: 1) Computational Concepts, used during the act of programming, such as sequences, loops, parallelism, events, conditions, operators and data; 2) Computational Practices, focused on metacognition and using interactivity, testing and debugging, reuse, abstraction and modelling; 3) Computational Perspectives, which, after appropriation of the concepts, encompass the subjectivity and point of view of each human being towards the ideas presented and the world which are materialised through interaction and questioning.

Based on the analysis of several studies, Shute et.al (2017) suggest six dimensions in CT, adding the following processes to the decomposition, abstraction and creation of algorithms: 1) Debugging, which enables the identification and correction of possible errors; 2) Iteration, which enables the refining of solutions through the repetition of processes until the ideal results are achieved; 3) Generalisation, which aims at the application of correct solutions in similar problems. According to Kafai *et al*, (2020) CT displays some similarities with Simon Sinek's Golden Circle Theory (2009), and is divided into three dimensions: 1) Cognitive, alluding to the measurable part of CT, from the creation of the algorithm to practices such as modelling or iteration; 2) Contextual, comprehending the interactions, the author's identity and the creation of meaningful applications; 3) Critical, based on the concept of critical thinking, the driver of social change through creative processes. In short, since the paper published by Wing (2006), Computational Thinking has been associated with numerous thought processes, especially abstraction, algorithm construction, decomposition, pattern recognition, data representation and problem solving.

1.1.2 Computational Thinking in Primary Education

Creating opportunities that promote the development of CT in children and young people involves preparing them for future challenges. However, the main challenge is understanding how to best create these opportunities in school settings in an equitable and efficient manner, taking students' uniqueness and background into consideration. Worldwide interest in the inclusion of CT in schools has been gradual, although currently several gaps may be observed in its implementation (Fantinati & Rosa, 2021).

In fact, this discussion had already been raised in the past by Papert (1993), who described the transformative potential and learning possibilities of computing, and the importance of its implementation at both public and democratic levels: "The only question that remains unanswered is, will such alternatives be created democratically? Will state education lead the way or, as in most situations, will the change first enhance the lives of the children of the wealthy and powerful (...)" (p.6).

As far as Fantinati and Rosa (2021) are concerned, the current obstacles to the integration of CT in schools, especially in Primary Education (PE), are the lack of teacher training, the inexistence of a proper curriculum, the scarcity of valid assessment methods for measuring CT and the absence of unanimity on a concrete definition that is consensual among authors and researchers. The lack of initial and continuous teacher training is an obstacle to the introduction of CT in schools

(Shute *et al*., 2017). In fact, for students to have the possibility of developing this competence during their schooling, teachers need to acquire adequate knowledge on the concept, as well as an understanding of how to teach it most effectively to their students, and the creation of such opportunities is crucial not only in computing-related subjects but also at a transversal level (Ramos & Espadeiro, 2014; Yadav *et al*., 2014).

As regards the integration of CT in the school curriculum, the current literature describes two distinct approaches: 1) integration of the concept in Programming or Computer Science subjects in PE (Valente, 2016); 2) integration of the concept during the course of daily classroom practices, whereby it assumes a transversal character (Shute *et al*., 2017). The report "Reviewing Computational Thinking in Compulsory Education" (Chioccariello *et al*., 2022) reveals that 25 countries in Europe already include curricular initiatives for an introduction to programming and CT development in their Basic Education, highlighting, among other motivations, the importance of fostering skills such as critical thinking, creativity, communication, collaboration, problem solving and logical reasoning.

Among the various integration models, the contextual adaptation conducted by each country should be noted which 1) studies the feasibility of creating specific curricular components; 2) updates the already existing curricular programme directly related to Information and Communication Technologies; 3) from a cross-cutting perspective, relates CT to other curricular areas, especially mathematics. In Valente's (2016) view, these integration models are what define the materials and contents that should be addressed during teacher training and applied during the course of teaching practice. England, for example, adopted a new area of knowledge in 2014, referred to as Computing, which features throughout primary education, thus ensuring the digital empowerment of the students and the integration of CT in their learning: "The development of computational thinking enables students to master the skills involved in solving a wide range of problems (...). Computing should, therefore, become a fully-fledged subject in its own right, with a deeper link to other subjects". (ES, 2015).

Accordingly, Berry (2013) highlights the important role played by the Computing at School project, whose guide "Computing in the National Curriculum: a guide for primary teachers" has been deemed an example by major international institutions. Other examples are Poland, which in 2017 established a new curriculum for computer science from the 1st year of schooling; France, which reformulated the national curriculum for PE and secondary school in 2015 to include programming and CT; Spain, which included programming in secondary school as an optional subject for the whole country and in primary school in the Navarra, Madrid, and Catalonia regions; and Finland and Sweden, which, in the wake of curriculum reforms in 2016 and 2017, already include programming from the 1st year of primary school (Chioccariello *et al*, 2022; ES, 2015; Google for Education, n.d.).

The introduction of CT in schools may be conducted through activities related to Computer Science, such as programming, which currently includes an endless number of existing learning tools, such as Scratch, Kodu, Blocky, Minecraft, Alice, Tynker, Ubbu, among others. These block-based programming environments are usually designed to be used by children and young people, enabling the development of CT-related processes (Piedade et. al, 2019; Ramos & Espadeiro, 2014). In addition to programming, the National Research Council [NRC] report (2011) acknowledged other activities that develop this competence, among which, educational robotics, digital narratives, game creation, simulator exploration and, of particular relevance within the scope of this paper, unplugged activities (Computer Science Unplugged). Finally, Valente (2016) mentions that CT can also be promoted transversally, through several activities included in other subjects. Its implementation should focus on themes and contents related to STEM areas: Science, Technology, Engineering and Mathematics.

According to Weintrop *et al*. (2015), these subjects are strongly linked to Computational Thinking: "From a pedagogical perspective, the thoughtful use of computational tools and skillsets can deepen learning of STEM content. The reverse is also true - namely, that science and mathematics provide a meaningful context (...) within which CT can be applied" (p.3). In Portugal, CT has been integrated into the curriculum through its inclusion in the subject of computer science, between the 5th and 9th grades, but also across other subjects, such as Portuguese, Mathematics and Sciences and through the subject of Information and Communication Technologies (ICT) (Piedade *et al*., 2019).

Currently, the MatemaTIC pilot project aims to create resources and training contexts for primary school teachers to support the development of competences in the areas of Computational Thinking, and there is a consensus that board games can create spaces for this learning.

1.1.3 Unplugged Activities

The teaching of computer science, programming and CT now plays a significant role in the 21st century. As already observed, many countries have restructured their curricula to include these concepts in their students' learning, providing them with the possibility of developing specific skills and preparing them for a digital future (Guzdial, 2015). Waite (2017) states that "Teaching activities take place in situated contexts" (p. 22), and there are currently three essential scenarios for CT development: 1) Programming; 2) Educational Robotics; 3) Unplugged Activities.

According to Papert (cited in Kestenbaum, 2005), programming is a powerful tool that promotes the construction of a highly sophisticated and rigorous level of thinking, which is necessary, for example, in mathematics, while one of the teaching activity's main challenges is to understand that these and other concepts related to computer science may be best introduced in a transdisciplinary manner (Waite, 2017).

As stated by Kestenbaum (2005), «Papert's championing of programming as a means to develop thinking in other subjects provides an attractive rationale for teachers to situate computing in cross-curricular contexts" (p.22). In fact, the level of students' appropriation of computer science-related knowledge may prompt teachers to consider not only the use of block programming languages, but also educational robotics (Battal *et al*., 2021).

However, many computer science concepts can also be taught without the use of a computer (Brackmann *et al*., 2017). The first reports on the inclusion of unplugged activities in PE date back to 1997, when Bell *et al*. (1998) released "Computer Science Unplugged...Off-line activities and games for all ages" and presented a set of computer science concepts without the use of a computer. In Waite's (2017) estimation, "teaching computing without a computer, or 'unplugged pedagogy', could be classified as an instructional technique" (p.29).

Moreover, these activities may have a highly relevant role for students, whose access to technology is non-existent or limited, thus providing equal opportunities (Battal *et al.*, 2021). Bell and Vahrenhold (2018) define unplugged activities as "a widely used collection of activities and ideas to engage a variety of audiences with major CS ideas, without having to learn programming or even use a digital device" (p. 497). In addition to introducing a variety of CS concepts, Unplugged Activities can create a fun, motivating, and challenging environment for students, and is an approach that has been acknowledged as "one of the most used and most successful strategies" (Waite, 2017, p.29) to teach computing and CT development. Although implemented without the use of computers, they may eventually be used as tools to support the construction and publication of materials (Battal *et al.*, 2021).

Nishida et. al (2009) also describe other characteristics that may be found in unplugged activities: 1) They are usually conducted through games or challenges, promoting a playful, interesting and motivating approach; 2) They are kinesthetic, as they resort to the use of various physical objects, such as cards, stickers, paper, pens, markers, chalk, boards, ropes, dice, board games, etc. 3) They are interactive and, in addition to encouraging students to find solutions to problems through experimentation, they foster peer work and the development of communicative skills; 4) They are easy to prepare and, in most cases, require low-cost materials available in schools, whose exploratory script is created and/or adapted by the teacher; 5) They are very modular, permitting constant reformulations and contextual adaptations to activities, thus giving rise to a beneficial exchange of ideas; 6) They are creative, designed on the basis of several fantasy and/or thematic elements, and therefore contribute to higher levels of student engagement. In view of the above, board games are a type of unplugged activity that meets the afore-mentioned requirements.

Ching *et al.* (2018) state that "several board games are specifically designed to develop players' computational thinking" (p.567). Thus, the following section discusses a number of concepts related to board games, as well as their conceptualisation, pedagogical use and possible contributions to the development of CT.

1.1.4 Board games and Eurogames: back to a past turned modern

Huizinga (1949/1980), author of the classic Homo Ludens: A study of the play-element in culture, argues that "play is older than culture, for culture, however inadequately defined, always presupposes human society". In this regard, Silva and Kodama (2010) highlight the presence of play in the cultural life of various peoples, as well as its importance for children, who by playing from an early age, create opportunities for the development of various skills.

Corroborating Jean Piaget's theory, Linaza (2013) suggests that being inseparable from thought, play is essential to all educational activities and can provide more ambitious explanations of intellectual processes. Prado (2018) considers that the pedagogical differentiation associated with the use of a game in the classroom gives rise to dynamic and active learning, while Kishimoto (2004) highlights the importance of the purpose of the game used, arguing that it is the pedagogical dimension that allows it to be termed as an "educational game".

As seen in the previous section, the research related to unplugged activities has suggested that board games, as unplugged activities, create a very interesting and complex space for the development of Computational Thinking, encompassing several forms of reasoning and learning (Lee *et al.*, 2020). Berland and Lee (2011) define a board game as a playful activity, quite common among groups, which usually involves a varied set of rules and styles of play. Additionally, Wu (2018) states that games generically described as interactive, namely card, board, dice, etc., played between groups or head-to-head, on a table or other flat surface are also known as tabletop or board games. More recently, Sousa and Bernardo (2019) presented a more global definition: "By board games we mean all analog games played on a table" (p.1). Ç

Regarding this type of activity, it is possible to observe a quasi- return to the past. Board games have seen a considerable increase in demand and it is estimated that by 2023, this industry may attain an annual growth rate of approximately 17%, and be worth around 12 billion dollars (Sousa & Bernardo, 2019). This interesting rise in the digital age has been gradual and is largely due to the influence of the German-style strategy games of the 1960s (Berland & Lee, 2011; Woods, 2019).

However, defining a modern board game is no easy task. According to Woods (2019), a modern board game is described as a "manufactured commodity, designed and published at a particular time in history, and produced for a particular market and for essentially commercial reasons" (p.17).

Woods (2019) considers that there are three types of board games: 1) classic board games, which describe the "non-proprietary games that have been passed down from antiquity and whose authorship is presumed to emerge from multiple iterative changes over time" (p.17) such as Chess, Checkers and Hnefatafl; 2) mass-market games, which refer to the "commercial titles that are produced and sold in large numbers year after year, and which constitute the common perception of commercial board games" (p.17), such as Monopoly, Scrabble, Trivial Pursuit and Pictionary; 3) hobby games, "that are differentiated from other forms by their appeal to a particular segment of the population over the last half-century" (p.17), subdivided into wargames, role playing games, collectible card games and Eurogames.

Listed by Woods (2019) as one of the sub-genres of hobby games, Eurogames appeal to a new way of playing, associating and cooperating, and have very specific characteristics: they are relatively accessible games, with simplified rule systems that prioritise game mechanics over theme, as well as choice and decision-making over randomness. They are designed for groups, restricted in terms of time and may be won by means of multiple pathways. Sousa and Bernardo (2019) also highlight that Eurogames are known for their distinctive game mechanics, their originality and the quality of their constituent components.

As a result of Berland and Lee's (2011) use of Matt Leacock's board game Pandemic in 2011 to code students' discursive interactions in order to identify Computational Thinking concepts, the scientific community clearly awoke to the potential of this activity. On the other hand, the board game industry has also been attentive and in recent years several board games specifically designed for computer science enthusiasts have been published: Robot turtles, Coding farmers, CodeMonkey, RobotWars, King of Pirates, Doggy Code, CodeMaster, etc., (Lee *et al.*, 2020; Wu, 2018). Nevertheless, although unplugged activities are currently a popular approach (Bell & Vahrenhold, 2018), the use of modern board games, more specifically Eurogames, in classroom contexts still appears to be scarce.

Thus, this systematic literature review sought to analyse the empirical studies published in the field of developing Computational Thinking through board games and thus identify the current state of research and possible gaps.

2. DESIGN AND METHOD

The systematic literature review process assists the researcher in understanding the current state of the art, and in learning about what has already been studied, as well as possible gaps and future needs related to the field of research (Lo, 2020). Although unplugged activities are currently widely used in educational settings, their real contribution needs to be more fully assessed (Bell & Vahrenhold, 2018). In this regard, Berland & Lee (2011) argue that it is necessary to understand how the complexity and design of Eurogames, as unplugged activities, invoke Computational Thinking, considering that these new contemporary board games may constitute an important tool for learning this new literacy.

Thus, the present study conducted a systematic literature review to analyse the studies published in the field of CT development through board games. Based on Newman & Gough (2020), it followed a set of steps, common to most systematic review processes, which are adapted to the study in question. A review protocol was followed, seeking to minimise any bias and to ensure scientific rigour which is essential for a similar replication by other researchers (Kerres & Bedenlier, 2020; Newman & Gough, 2020). The details of each of the steps involved in the whole process are presented below.

2.1. RESEARCH QUESTIONS AND CONCEPTUAL FRAMEWORK

As a point of departure for the systematic review process, upon definition of the research objective, we sought to establish a set of guiding questions to define and develop the literature review. Thus, this study aimed to answer the following questions:

QI_1. What are the demographics of the studies examined with respect to year of publication, journals of publication, country of origin, authors and keywords used?

QI_2. What theoretical frameworks were used to define the CT construct in the studies examined?

QI_3. In what educational context are board games typically used to promote CT?

QI_4. What kind of board games are used to promote CT skills?

QI_5. What research methodologies were used in the studies considering the research design, variables, participants and samples, instruments, data collection sources and processes and analysis?

QI_6. What are the main findings signalled in the studies examined?

The research questions were operationalised through a review protocol (Kerres & Bedenlier, 2020; Newman & Gough, 2020), which gave rise to the conceptual framework of the study. The literature review on CT development through board games revealed that this is still a highly incipient field. Thus, in addition to studies published in scientific journals, it was decided that studies published in conferences would also be included, considering the current nature of the data provided to be important. It should also be noted that this study only considered studies of an empirical nature, with access to data from participants in school settings, excluding studies describing activities, objects, methods and techniques, as well as all grey literature on the topic.

3. FIELD WORK AND DATA ANALYSIS

3.1. SEARCH STRATEGY AND INCLUSION CRITERIA

In order to find studies focusing on the use of board games as a vehicle to promote the development of Computational Thinking, a systematic literature review process was defined with recourse to the digital databases SCOPUS, ISI Web of Science, ERIC, ACM and EBSCO, since they are currently widely-recognised and capable of concentrating a large number of publications from acclaimed scientific journals. Their tools enable researchers to optimise their research, making it more solid and credible.

The research process, in the aforementioned databases, consisted of searching for empirical studies containing the keywords "Computational Thinking" AND "Boardgames" OR "Board Games" OR "Tabletop games" (Figure 1). The search sought to identify articles published in the period between 2006, the year in which the concept of computational thinking was defined, and 2021. The research protocol was adapted and organised according to the steps defined by Newman & Gough (2020), which are presented below.

Figure 1. Search equations used in each database

SCOPUS

- (TITLE-ABS-KEY ("computational Thinking") AND TITLE-ABS-KEY ("board games") OR TITLE-ABS-KEY ("tabletop games") OR TITLE-ABS-KEY ("boardgames") PUBYEAR > 2006)

ISI Web of science

- TS=(("board game$" or boardgame$ or tabletop*) and "Computational Thinking")

ERIC

- abstract: (boardgames or "board games" or "tabletop games") and "Computational thinking" pubyearmin:2006 pubyearmax:2021 OR title: (boardgames or "board games" or "tabletop games") and "Computational thinking" pubyearmin:2006 pubyearmax:2021 OR descriptor: (boardgames or "board games" or "tabletop games") and "Computational thinking" pubyearmin:2006 pubyearmax:2021

ACM Digital Library

- [Title: "computational thinking"] AND [[Title: boardgames] OR [Title: "board game*"] OR [Title: "tabletop game*"]] AND [Publication Date: (01/01/2006 TO 12/31/2021)] OR [Abstract: "computational thinking"] AND [[Abstract: boardgames] OR [Abstrat: "board game*"] OR [Abstract: "tabletop game*"]] AND [Publication Date: (01/01/2006 TO 12/31/2021)] OR [Keywords: "computational thinking"] AND [[Keywords: boardgames] OR [Keywords: "board game*"] OR [Keywords: "tabletop game*"]] AND [Publication Date: (01/01/2006 TO 12/31/2021)]

EBSCO

- TI: Computational thinking AND (boardgame* or "board game* or tabletop game*) OR KEY: Computational thinking AND (boardgame* or "board game* or tabletop game*) OR ABS: Computational thinking AND (boardgame* or "board game* or tabletop game*)

Source: Own elaboration

The selection of eligible studies for the systematic literature review considered the following inclusion and exclusion criteria.

Inclusion criteria:

- Studies related to the use of board games in the development of Computational Thinking in educational contexts, namely in primary, secondary and/or higher education.
- Studies of an empirical nature, i.e. with a research dimension.
- Studies published in peer-reviewed scientific journals or conferences and available in the SCOPUS, ISI Web of Science, ERIC, ACM and EBSCO databases.
- Studies published in English, Portuguese and Spanish to be read and understood by the authors.
- Studies available online in full and open access format.
- Studies published between 2006 and 2021.

Exclusion criteria:

- Studies published in book chapters, posters and grey literature.
- Studies published as systematic literature reviews.
- Studies not focused on the use of board games in the development of Computational Thinking.
- Studies not focused on education.
- Studies published in other languages.
- Duplicate studies in the databases used.
- Studies available in restricted access or without access to full text.
- Studies published prior to 2006.

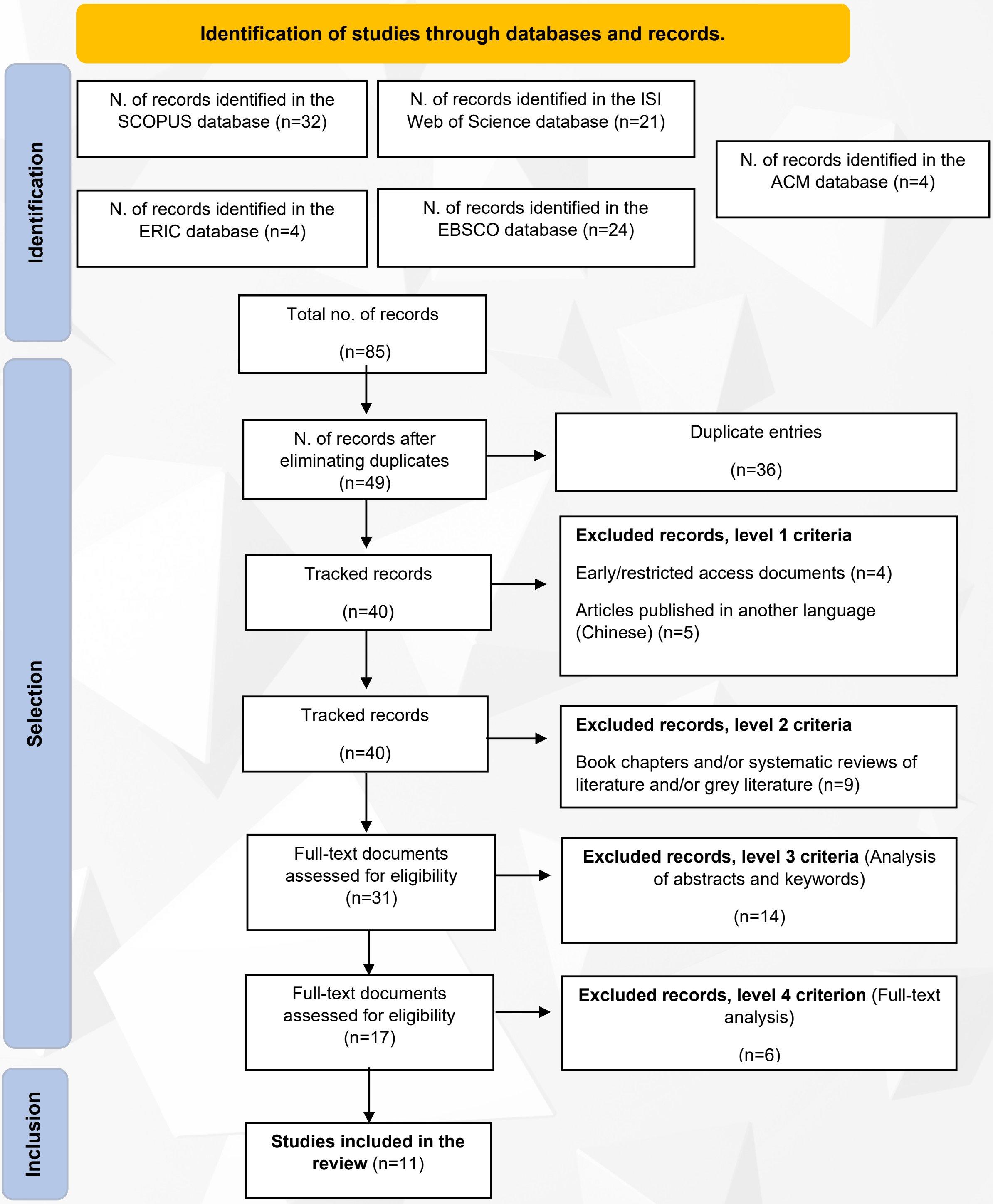
3.2. STUDY SELECTION

The organisation of the research protocol drew on the assumptions set forth in the Preferred Reporting Items for Systematic Literature Reviews and Meta-Analyses (PRISMA) framework proposed by Page *et al.* (2021). The main objective of this framework is to ensure credibility, reliability, consistency and accountability when documenting the entire systematic literature review performed. According to Page *et al.* (2021), this approach "can provide syntheses of the state of knowledge in a field, from which future research priorities can be identified" (p.1).

When consulting the referenced databases, 85 papers were found, of which 32 were located in SCOPUS, 21 in ISI Web of Science, 4 in ERIC, 4 in ACM and 24 in EBSCO. This initial sample of studies was iteratively reduced by excluding duplicate records obtained from the digital libraries used. The first analysis eliminated a total of 36 duplicate records. In the next step, all early access, restricted, incomplete and/or inaccessible documents, as well as papers published in different languages from English, Spanish and/or Portuguese were entirely removed, resulting in a reduction of 9 articles. In the subsequent phase, all the articles corresponding to book chapters, systematic literature reviews and/or grey literature were excluded, accounting for a total of 9 excluded records. The 31 eligible papers were then analysed in detail regarding the identified keywords and abstracts described, leading to a selection of the final sample of studies, after applying the inclusion and exclusion criteria. Thus, during this stage of analysis, the researcher decided to include firstly 10 studies, since they related the keyword "Computational Thinking" to at least one of the keywords "boardgames", "board games" or "tabletop games" and, subsequently, a further 7 studies as they proved to be relevant within the scope of the research, after analysis of the respective abstracts.

Finally, the full texts of the 17 articles assessed for eligibility were also analysed, leading to the exclusion of a further 6 articles. In short, a total of 11 articles were considered suitable for inclusion in this systematic review. The entire process is summarised in the PRISMA flowchart, which is illustrated in Figure 2.

Figure 2. Systematic review procedural flow based on the PRISMA approach



Source: PRISMA Flow Diagram adapted from Page *et al.* (2021)

3.3. CODING OF STUDIES

In order to code the studies, the following were used: AU - Name of authors and date of publication, TI - title of publication, TP - type of publication (JA=Journal Article; CA=Conference Article), SL - Schooling Level (1PE= 1st – 4thGrades/Primary Education; 2PE= 5th – 6thGrades /Primary Education; LSE= 7th – 9thGrades /Lower Secondary Education ; USE=Upper Secondary Education; HE=Higher Education; ND=Not Determined), AG - Age Group; TY - type of instrument used (I=Interview; O=Observation; T=Test; Q=Questionnaire; S=Survey), CO - country of origin. The 11 analysed studies are ordered in Table 1 below by date of publication.

Table 1. Coding of the selected studies

AU	TI	TP	SL	AG	TY	CO
(Berland & Lee, 2011)	Collaborative strategic board games as a site for distributed computational thinking.[1]	JA	HE	17-19 years	O	USA
(Apostolellis et al., 2014)	RaBit EscApe: A board game for computational thinking. [2]	CA	1PE	8-10 years	O	USA
(Berland & Duncan, 2016)	Computational Thinking in the Wild: Uncovering Complex Collaborative Thinking Through Gameplay. [3]	JA	HE	N/A	O/T/I	USA
(Tsarava et al., 2018)	Training Computational Thinking through board games: The case of Crabs & Turtles. [4]	JA	HE	22-52 years	O/T/Q	Germ any
(Yen & Liao, 2019)	Effects of Cognitive Styles on Learning Performance and Gaming Behavior in a Programming Board Game. [5]	JA	2PE	10-11 years	T	Thail and
(Wangenheim et al., 2019)	Splash code - a board game for learning an understanding of algorithms in middle school. [6]	JA	1PE/ 2PE	8-12 years	Q/T	Brazil
(C.-Y. Tseng et al., 2019)	Exploring evidence that board games can support computational thinking. [7]	CA	LSE	12-13 years	T	Hong Kong
(Lee et al., 2020)	Introducing coding through tabletop board games and their digital instantiations across elementary classrooms and school libraries. [8]	CA	2PE	N/A	I/O/S	USA
(Kuo & Hsu, 2020)	Learning Computational Thinking Without a Computer: How Computational Participation Happens in a Computational Thinking Board Game. [9]	JA	LSE	11-12 years	O/T	Thail and
(S.-Y. Wu & Su, 2021)	Behavior and cognition processing of educational tabletop coding games. [10]	JA	1PE	5-6 years	O/T/I	Thail and
(Hsu & Liang, 2021)	Simultaneously Improving Computational Thinking and Foreign Language Learning: Interdisciplinary Media With Plugged and Unplugged Approaches. [11]	JA	1PE	8-10 years	T/Q	Thail and

Source: Own elaboration

4. RESULTS

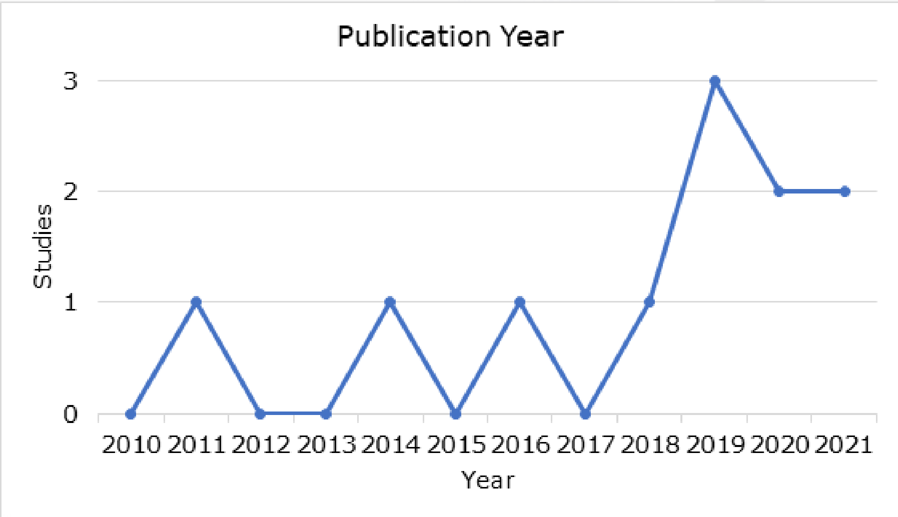
The initial search conducted in the above-mentioned databases returned a total of 85 records. Following application of the selection criteria, 11 articles were included in the detailed analysis of the results, based on the established research questions.

4.1. DEMOGRAPHIC CHARACTERISTICS OF THE STUDIES

Of the 11 selected publications, 7 were articles published in scientific journals and 4 were articles published in proceedings of specialty conferences. The publication dates range from 2011 to 2021, however only from 2018 onwards are there studies published sequentially until 2021, with no publication record in 2012, 2013, 2015 and 2017. This distribution, by year of publication, may be observed in Figure 3.

Despite the inconsistency and the small sample size, it is possible to observe a gradual increase of interest in studies addressing the development of Computational Thinking through board games. The studies were mainly developed by two researchers (N=6), and one study by a team of 7 researchers. Although conducted in 5 different countries, the USA and Thailand were the countries with the highest number of studies, namely 4 in each country. The remaining studies were distributed among Germany, Brazil and Hong Kong.

Figure 3. Year of Publication of the Studies analysed



Source: Own elaboration

With regard to the incidence of keywords used by the authors in their studies, "Computational Thinking" (n=8), "Board Games" (n=5), "Tabletop Games" (n=2), "Unplugged Activities" (n=2), "Game Based Learning" (n=2) and "K-12 Education" (n=2) were considered the most commonly used keywords. However, a total of 12 terms directly linked to Computer Science and Computational Thinking are identifiable in the remaining distribution of keywords: "Coding Education" (n=1), "Computer Science Education" (n=1), "Computational Participation" (n=1), "Critical Thinking" (n=1), "Programming Education" (n=1), "Coding" (n=1), "Abstraction" (n=1), "Pattern Recognition" (n=1), "CS Unplugged" (n=1), "Elementary School Coding" (n=1), "Algorithms" (n=1) and "Programming" (n=1). The weight of each of the keywords identified in the studies is illustrated in Figure 4.

Figure 4. Keywords of the studies

Source: Own elaboration

4.2. THEORETICAL FRAMEWORKS USED IN THE STUDIES

Another strand of our study focused on the analysis of the theoretical frameworks used by the different authors to define the concept of computational thinking. Table 2 systematises the data relating to the authors, the concept and the number of occasions the authors are cited in the studies.

Table 2. Main Theoretical Frameworks Identified in the Construction of Computational Thinking

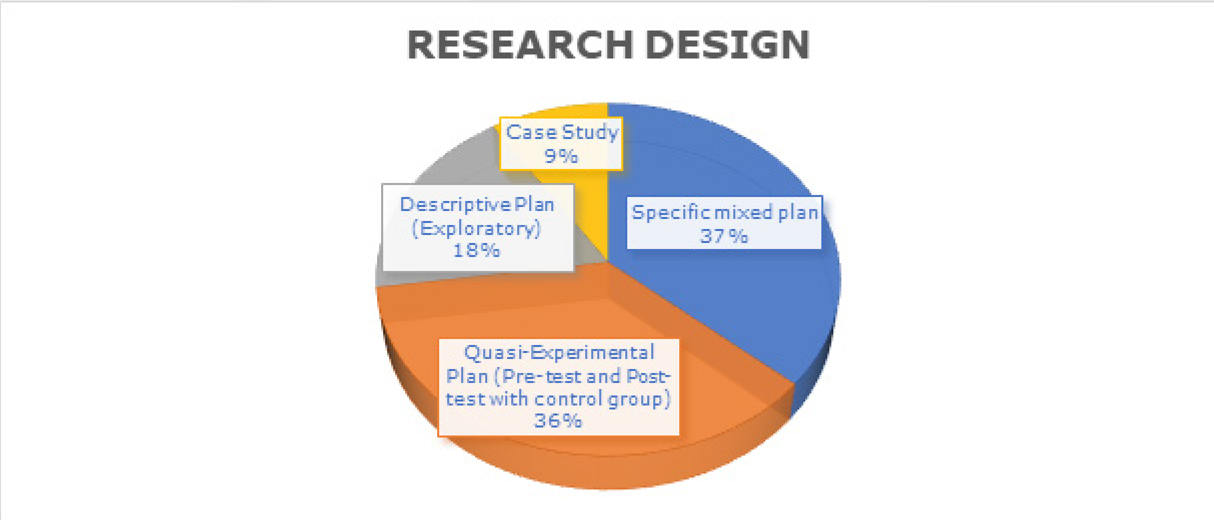
	Authors	Definition	Cited in the studies	Frequency
Predefinition of the Concept	(Papert,1980)	Author and creator of the theory of constructionism, he recognises Computational Thinking as an ideal procedural thinking for problem solving and programming.	[1]; [3]; [4]; [5];	4
Definition of the concept	(Wing, 2006)	The author defines, the concept of Computational Thinking for the first time, identifying the various procedural phases of this cognitive skill: abstraction; problem decomposition; problem reformulation; automation; testing.	[1]; [2]; [4]; [5]; [6]; [7]; [9]; [10]	8
	(Barr & Stephenson, 2011)	They create a model focusing on the identification of CT competences and possible articulation with other disciplines.	[2]	1
	(CSTA & ISTE, 2011)	The International Society Technology Education (ISTE) in partnership with Computer Science Teacher Association (CSTA) have developed a list of six concepts to describe CT: problem formulation; data organisation and analysis; abstraction; automation through algorithmic thinking; evaluation; generalisation.	[5]	1
	(Brennan & Resnick, 2012)	The authors suggest a three-dimensional framework: computational concept, practice and perspective, mainly using Scratch in Primary Education.	[2]; [3]; [4]; [5]; [7]; [10]	6
	(Selby & Woollard, 2016)	The authors developed a framework for CT and evaluated the concept through qualitative observation. The proposed definition of CT includes abstraction, decomposition, algorithmic thinking, generalisation and evaluation, refuting data manipulation due to the comprehensiveness of the term as a competence.	[10]	1
	(Grover & Pea, 2017)	The authors propose a framework centred on the thinking process in which programmers engage in problem solving through concepts (Logical Thinking; Algorithmic Thinking; Pattern Recognition; Abstraction and Generalisation; Evaluation and Automation) and practices (Problem Decomposition; Artifact Creation; Testing and Debugging); Interactive Refinement; Collaboration and Creativity) of Computational Thinking.	[7]; [3]	2
Relationship with Unplugged Activities	(Bell et al., 1998)	The authors advocate valuing and using unplugged activities to develop Computational Thinking and programming skills.	[5]; [8]	2
	(Engle et al., 2012)	The author develops an expansive model of transferability of unplugged computational ideas to digital environments.	[8]	1
	(Kotsopoulos et al., 2017)	The authors propose a pedagogical framework for the development of Computational Thinking through four experiences: "Unplugged"; "Tinkering"; "Making"; "Remixing".	[9]	1
Relationship with Board Games	(Berland & Lee, 2011)	The authors propose the intentional creation of board games and their use as a vehicle for promoting Computational Thinking.	[2]	1
	(Roungas, 2016)	The author introduces a model for designing educational games.	[4]	1
	(Battistella & Wangenheim, 2016)	The author develops the ENgAGED process for developing educational games, which encompasses the instructional design process and game design process.	[6]	1
	(Hou, 2016)	The author proposes the development of educational board/table games considering cognitive analysis and the goals of Bloom's Taxonomy.	[10]	1
Assessment	(Dagiene & Stupuriene, 2016)	The authors created the Bebras Computer Challenge to introduce computational thinking to students. This model is used in over 50 countries and consists of applying questions and solving problems geared towards developing computational thinking and logical reasoning.	[9]	1
	(Grover & Pea, 2018)	The authors design geometric questions and mathematical problems based on pattern recognition and generalisation and abstraction.	[7]	1
	(Wangenheim et al., 2019)	The authors adapt the MEEGA+ evaluation model (Petri et al., 2018) and create MEEGA+Kids to evaluate the quality of games targeting Computer Science.	[6]	1

Source: Own elaboration

4.3. METHODOLOGICAL DESIGN OF THE STUDIES

Upon an in-depth analysis of the selected studies, the preference for mixed research methodologies was evident (n=6), with qualitative and quantitative approaches taking predominance in the research. Of the remaining studies, three were identified as qualitative research studies, while a low prevalence of solely quantitative studies was observed, with only two studies of this nature. With regard to the research design, the "Quasi-Experimental" plan (n=4) with "Pre-test and Post-test with control group" approach, as well as the "Mixed Specific" plan (n=4), with "Evaluative" and "Exploratory" approaches, were the most commonly mentioned.

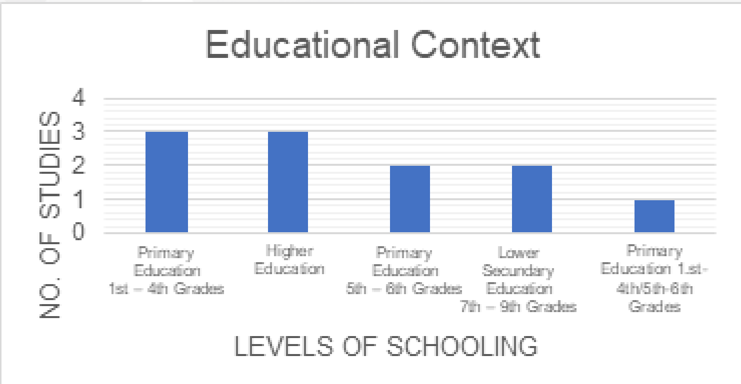
Figure 5. Research Design of the studies analysed



Source: Own elaboration

When examining the published studies regarding the target group, the participation of students from all education cycles, with the exception of Upper Secondary Education was found. It should also be noted that some of the studies were conducted with students in Higher Education, and one study included the participation of students from two educational cycles (See Figure 6).

Figure 6. Educational Context Relating to the Sample of the Studies Analysed



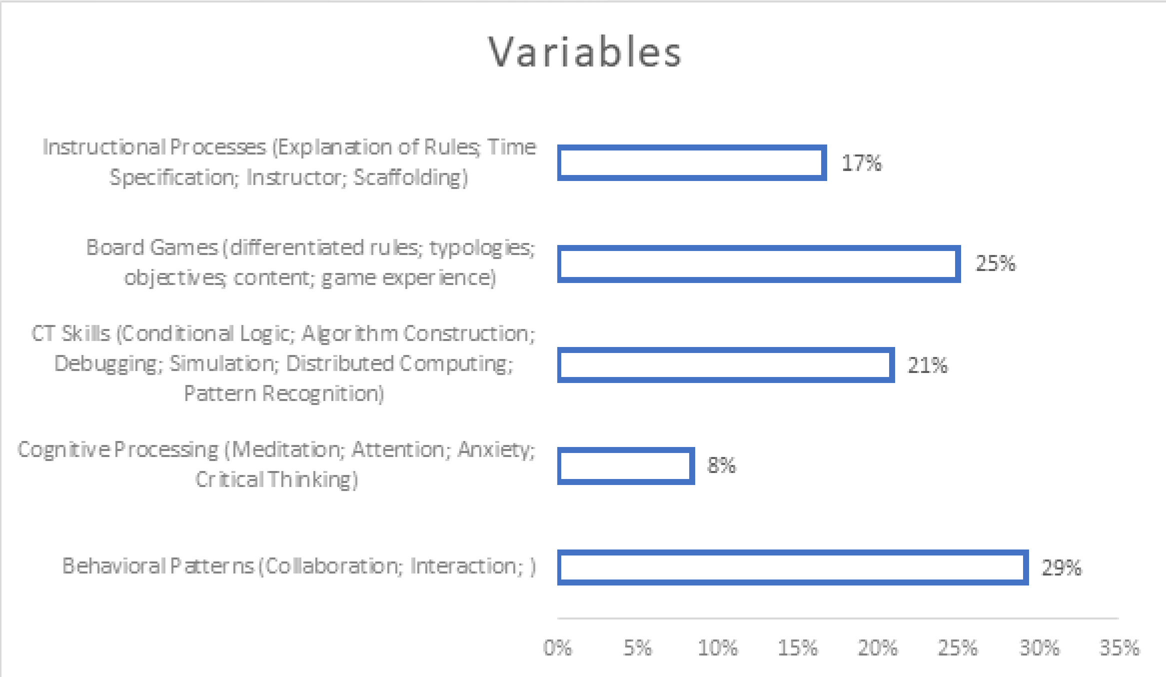
Source: Own elaboration

When analysing the sample sizes, a participant range of 1-365 was observed, with 7 studies encompassing a sample size of 1-49, 2 studies with a sample size of 50-99, 1 study with a sample size above 100 participants and one study with an undefined number of participants. It should be noted that 90% of the analysed studies point to samples smaller than 100 participants, which means that their results cannot be generalised.

As regards the data collection methods used, the results suggest some degree of diversity due to the nature of each study. Thus, overall, over half of the analysed studies used more than one type of instrument. The most commonly used instruments to collect quantitative data were "tests" (n=8), followed by "questionnaires" (n=3). On the other hand, for qualitative data collection, the most commonly used methods and techniques were "observation" (n=6) and "interviews" (n=3). The quantitative data collected were, as a rule, analysed using inferential statistics, such as the comparative analysis of means using "t-tests", "f-tests", "Analysis of Variance (ANOVA)", "Analysis of Covariance (ANCOVA)", "Dunn's Test" and "Tukey's Test". However, for the purposes of qualitative analysis, the data were analysed mainly by means of "Content Analysis" or "Discourse Analysis", both normally using coding and content analysis techniques.

A detailed analysis of the studies allowed us to identify a diversity of variables that each study sought to measure or analyse. Thus, most of the studies, 29%, presented variables related to "Behavioural Patterns", with an emphasis on collaboration and interaction. Variables related to "Board Games" were observed in 25% of the studies, highlighting the use of different games, game experience or differentiated rules. 21% of the studies, used variables related to "CT Skills", such as the construction of algorithms or pattern recognition. «Instructional Processes" and "Cognitive Processing" were the categories with the fewest variables present in the analysed studies, 17% and 8% respectively.

Figure 7. Variables identified in the studies, grouped into 5 categories according to their nature



Source: Own elaboration

4.4. CHARACTERISTICS OF THE BOARD GAMES USED

In this section, the board games used in the analysed studies are identified and described as well as the dimensions worked on during their application. For the organisation of the data, Woods' typology (2019), which subdivides modern board games into three types, was considered: classic games; mass-market games; and hobby games, in which Eurogames are included. The characterisation performed also considers the typology of Kishimoto (2004), who defines an educational game as one that is created with a pedagogical purpose. Thus, any game intentionally created by the authors of the analysed studies is referred to as "Educational Game".

Characteristics of the board games used based on the coding of the following categories:

- NM - Name of the game;
- DSR - Game designer and edition date;
- IMG - Game image;
- TP - Type of board game;
- DES - Description of the board game;
- DMS - Dimensions worked on with the game used;
- NO - Number of players;
- TM - Game time;
- LNG - Language of the game.

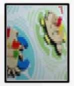
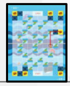
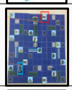
It is possible to analyse this characterisation shown in table 2 on the next page.

Before analysing the objectives and findings of the selected studies, it is important to consider the approaches used to implement board games in light of the development of Computational Thinking.

Based on Kishimoto (2004), most of the studies used educational board games (n=7), i.e., designed specifically for the purpose of the study and with a pedagogical intent associated with the research purposes. Regarding Woods' typology (2019), a higher predominance of "Hobby Games", namely "Eurogames" (n=3) was observed, followed by one study using a "Mass Market Game", namely "//CODE: On the Brink", especially designed for computer science education. It should be noted that none of the 'Classic Games' were used.

At least one of the studies (Hsu & Liang, 2021) used an unplugged approach along with a "plugged" activity, as a game board was developed and the mechanics of this type of activity were used, while the presence of educational robotics as a tangible programming element was observable. Of the 11 studies considered, only 4 studies clearly presented the research questions and/or hypotheses.

Table 3. Characteristics of the board games used

NM	DSR	IMG	TP	DES	DMS	NO	TM	LNG
Pandemic	Matt Leacock, 2008		Eurogames	The player is part of a pandemic containment team and must control the spread of four deadly viruses spreading across planet Earth, working collaboratively to find a cure.	Collaboration; Conditional Logic; Algorithm construction; Debugging; Simulation; Distributed computing;	2-4	45m	English
RaBit Escape	(Apostolellis, Stewart, Frisina & Kafura, 2014)		Educational game	Collaborative and competitive game in which players have to combine the polarity, orientation, shape and size of tangible pieces to form a path and thus help a rabbit escape from wild monkeys.	Logical Thinking; Data Analysis; Algorithmic Thinking; Collaboration;	N/A	N/A	English
Crabs & Turtles - A Series of Computational Adventures	(Tsarava, Moeller & Ninaus, 2018)		Educational game	This board game comprises three different games: 1) Treasure Hunt; 2) The Race; 3) Patterns. In 1), players have to manipulate turtles and coloured crabs to find efficient ways to collect treasures. In 2) they need to overcome mathematical puzzles in a race to victory by manipulating variables and conditions. In 3), players try to find patterns and certain cards as quickly as possible.	Algorithmic Thinking; Abstraction; Generalisation; Pattern Recognition;	1) 2 2) N/A 3) N/A	N/A	English; German; Greek
King of Pirates	(Yen & Liao, 2019)		Educational game	Players take on the role of pirates in search of treasure. Through programmed actions, players use logical reasoning to move their boats across the ocean and act tactically towards their opponents in an attempt to reach the greatest number of treasures.	Game behaviour; Computational Thinking (Global).	N/A	N/A	Thai English
Splashcode	(Wangenheim, Medeiros,Filho,Petri,Pinheiro,Ferreira & Hauck, 2019)		Educational game	Through programmed actions, players move their characters (small animals) across a board. At each turn, players overcome various obstacles, such as trees or puddles, in an attempt to reach the final "House" on the board.	Decomposition; Algorithmic Thinking.	3-6	15m	English Portuguese
Ghost Blitz	Jacques Zeimet, 2010		Eurogames	Players have to think and recognise the shape and colour of certain objects and act quickly. A pack of cards presents various images that must be analysed by the player. Playing at the same time, someone will reveal a card and then everyone must think about which object to pick up.	Pattern Recognition; Generalisation.	2-8	20m	English
Sushi Go	Phil Walker-Harding, 2013		Eurogames	Players must choose cards and place them on the table, passing the remaining cards to the player on their left until they have all been chosen. Each player must recognise certain patterns and score by calculating specific sets gathered during the game.	Pattern Recognition; Generalisation.	2-5	15m	English
//CODE: On the Brink	Thinkfun		Mass Market Game	Designed exclusively for learning computing concepts, the player faces 40 challenges across a colour-coded map. Each colour presents pre-programmed movements, executed by a robot. The number of challenges met will determine the winner of the game.	Intrinsic interest; Programming	1	N/A	English
Robot City	(Kuo & Hsu, 2020)		Educational game	Players take on the role of a robot that wanders the city in search of certain resources needed to accomplish specific tasks.	Collaboration; Behaviour.	4	N/A	Thai English
Interstellar Explorer	(Wu & Su, 2021)		Educational game	Players embark on a galactic adventure, taking on the role of spaceships in the search for new planets. Throughout the journey, they overcome various obstacles. The first to find the ideal planet is the winner.	Meditation; Attention; Behaviour.	2	20-30m	English
N/A	(Hsu & Liang, 2021)		Educational game	Using control cards, players guide a small robot around the board in an attempt to fulfil various tasks imposed by mission cards. Through an activity articulated with robotics, players work as a team to successfully complete each mission and acquire language skills.	Anxiety; Cooperation; Critical Thinking; Language.	N/A	N/A	English

Source: Own elaboration

4.5. MAIN RESULTS AND CONTRIBUTIONS OF THE STUDIES

In general, all the studies analysed used board games to subsequently assess their effectiveness against the proposed objectives and present conclusions directly related to the results obtained. When examining the conclusions of the respective studies, most of them showed quite auspicious results. Board games were generally considered as a highly potential resource for the development of Computational Thinking skills, namely "abstraction", "algorithmic thinking", "pattern recognition", "generalisation", "conditional logic", "debugging" and "simulation". (Berland & Duncan, 2016; Berland & Lee, 2011; Tsarava *et al.*, 2019; Tseng *et al.*, 2019; Wangenheim *et al.*, 2019).

Furthermore, two studies found improvements in other cognitive processes, namely logical reasoning and critical thinking (Hsu & Liang, 2021; Kuo & Hsu, 2020), which are also directly linked to computational thinking. Research has shown that the design of board games used in this context should consider the content of the game as well as the mechanics (Wu & Su, 2021). At least 5 studies considered that internalising rules and optimising behavioural, collaborative and cooperative strategies can benefit the quantity and quality of interactions capable of optimising Computational Thinking (Apostolellis *et al.*, 2014; Berland & Duncan, 2016; Berland & Lee, 2011; Kuo & Hsu, 2020; Yen & Liao, 2019). It was also possible to observe a study that suggested robotics as a complementary activity to the use of board games (Hsu & Liang, 2021). Improvements in the learning process due to the "quality of instruction" or "scaffolding" were also evidenced (Lee *et al.*, 2020; Yen & Liao, 2019), reported by at least two studies. Some studies also reported "trial and error" actions (Yen & Liao, 2019) as a fundamental approach to problem solving. At least one study advocated the inclusion of board games in training as an introductory activity to learn computational thinking (Tsarava *et al.*, 2018), while another mentioned the importance of including board games in library activities (Lee *et al.*, 2020). Finally, one of the studies highlighted the benefits of board games for interdisciplinary learning, relating them to "mathematics" and "programming" (Tsarava *et al.*, 2018). One study also reported a positive correlation between cognitive effects and the acquisition of learning associated with programming and computational thinking. (Yen & Liao, 2019).

5. DISCUSSION AND CONCLUSIONS

5.1. DISCUSSION

The results of this systematic literature review demonstrate that the number of empirical studies to use board games to promote CT is still relatively limited. Berland & Lee (2011), pioneers in the use of board games to develop CT, triggered the emergence of other relevant studies by stating that "many of these contemporary strategic board games could represent an important, and as-yet, under-considered foundation from which designers can intentionally develop computational thinking" (p.79). According to Bell & Vahrenhold (2018), unplugged activities began to gain prominence following their inclusion in the curricular reformulation of several countries, whereby a slight growth in the number of studies using board games to promote CT skills became perceptible.

Most of the studies, particularly over the last few years, have originated from Asian countries, which can be explained by the statements of So (2020): (...) countries such as Korea, Taiwan, Hong Kong, and China have launched national curricular reforms to address the current movement of CT education in K-12 education. This special issue, therefore, intends to provide insights into the current curricular reform movement of CT education in the Asian Pacific region". The most commonly used keywords in the studies examined were "Computational Thinking", "Board-games", Tabletop games", "Unplugged Activities", "K-12 Education" and "Game Based Learning", respectively. The preference expressed for these keywords reinforces the idea that board games are one of the unplugged approaches used to promote computational thinking in Primary Education, using the active methodology "Game Based Learning" (GBL).

With regard to the theoretical frameworks, the selected studies show that the existing literature on CT, although vast, is not unanimous and still needs to be further developed. Several researchers regard CT, as well as its procedural phases, slightly differently. Through an analysis of the 11 articles, the theoretical frameworks were categorised into 5 dimensions: 1) Predefinition of the CT concept; 2) Definition of the concept; 3) Relationship of CT with unplugged activities; 4) Relationship of CT with Board Games; 5) Assessment of CT. In each of the dimensions, the year of publication was considered, suggesting an existing relationship with the previously designed studies. The result of this analysis may be observed in Table 2 with our discussion geared towards those who contributed to the definition of the concept: Wing (2006), Barr & Stephenson (2011), CSTA & ISTE (2011), Bresnnan & Resnick (2012), Selby & Woollard (2014) and Grover & Pea (2018). A new era began with Wing's (2006) theory, which referred to CT as a core 21st century skill for all human beings. It is consensual that CT is a key skill that enables better adaptation to everyday problems. The author's initial ideas highlighted the phases of abstraction, problem decomposition, reformulation, automation and testing, serving as the point of departure for further research in the field of CT.

Although many authors have adapted and modified Wing's (2006) initial ideas, it is important to mention those which were identified during the analysis of the 11 selected articles. Thus, Barr & Stephenson (2011) devised a model focused on the identification of CT competencies and possible articulation with other disciplines, such as mathematics, computer science and natural science. The authors identified the concepts of data collection, analysis and representation, problem solving, decomposition, abstraction, algorithms, automation, parallelism and simulation. They distance themselves from Wing (2006) by focusing on data manipulation and algorithm construction, as well as by introducing the concepts of parallelism and simulation. Also in 2011, the CSTA in partnership with ISTE, built on Wing's (2006) initial ideas to create six concepts capable of describing CT: problem formulation, data organisation and analysis, abstraction, automation through algorithmic thinking, evaluation and generalisation. The main difference in the adaptations of Barr & Stephenson (2011) was the addition of the evaluation and generalisation concepts. In 2012, Brennan & Resnick designed a three-dimensional framework: concept, computational practice and perspective.

Focusing on the practical dimension, the authors suggested the use of the Scratch tool in Primary Education, describing four behaviours that enable project evaluation: abstracting and modelling; reusing and reformulating; testing and debugging; being interactive and incremental. Selby & Woolard (2013) also defined CT, in line with the ideas of Barr & Stephenson (2011), except for the terms associated with data manipulation. The authors considered the terms too broad and as such difficult to be considered as a skill. Furthermore, they reclaimed the terms generalisation and evaluation, cited by CSTA & ISTE (2011). Indeed, in 2018, Grover & Pea extended the discussion by proposing a broader framework, referring to programmers' problem-solving thinking as the basis of CT, suggesting the existence of Computational Thinking concepts (Logical Thinking; Algorithmic Thinking; Pattern Recognition; Abstraction and Generalisation; Evaluation and Automation) and practices (Problem Decomposition; Artifact Creation; Testing and Debugging; Interactive Refinement; Collaboration and Creativity). In sum, the analysed studies propose some frameworks which, besides seeking to define the concept, are a reference for students and teachers. As posited by Kalelio□lu *et al.* (2016), several researchers have adopted different angles to approach the phenomenon, even though there is no scientifically proven guarantee of the efficiency of the activities, programmes and assessments implemented.

Therefore, what appears to be more consensual is the contribution of all these frameworks, which ultimately serve as a framework for the design of activities aimed at the development of CT from a problem-solving perspective.

Methodologically, the reviewed studies evidence a clear preference for mixed methods. According to Kalelio□lu *et al.* (2016), quantitative and qualitative studies are frequently found within the scope of CT development, reinforcing the idea of an increasing focus on mixed approaches that encompass the two dimensions. Although the target audience of the analysed studies is quite heterogeneous, the results point to a greater number of studies developed in the early years of education. In fact, as stated by Battal *et al.* (2021), this context presents the ideal characteristics for the implementation of unplugged activities that promote the development of CT. It should be noted that higher education presented the same number of studies, thus suggesting the need to implement CT development practices in initial teacher training, since "teachers are generally unfamiliar with CT and have difficulty finding connections between CT and their current curricula" (Shute *et al.*, 2017, p.156). The analysed studies used several instruments in the data collection process, such as interviews, tests, questionnaires, surveys and also observation.

However, while on the one hand there are already validated tests that can measure CT skills, such as the CTS (Korkmaz *et al.*, 2017), the Fairy Assessment (Werner *et al.*, 2012), the Dr. Scratch (Moreno-León & Robles, 2015), the Bebras Task (Cartelli *et al.*, 2010), the CTt (Román-González *et al.*, 2017) and the CTA-CES (Li et.al, 2021), the applicability of these instruments may raise some questions in formal learning contexts, since teachers, by showing little confidence in teaching CT, reveal a lack of knowledge on how to apply the tests and assess a skill they do not master at all (Kang *et al.*, 2018). On the other hand, interviews have been somewhat undervalued, since they might foster highly interesting and more detailed explanations about the behaviours observed during the cognitive process, especially when referring to board games that prioritise peer interaction during the game flow (Tang *et al.*, 2020). Some of the analysed studies err by not presenting a solid and coherent structure, making it difficult to see that the application of board games may be regarded as an effective approach to develop CT. Even so, well documented studies have proven the contribution of board games to the development of CT, suggesting that there is an open path for all teachers who wish to engage students in learning CT content through interesting, challenging and complex activities such as board games (Berland & Duncan, 2016).

5.2. CONCLUSIONS

In short, the development of CT in the classroom has presented a huge challenge to teachers and educators throughout the world. It is necessary to reflect on the strategies to be used, the target audience, the method of application and, above all, on the most suitable resources and tools. The unplugged activities have emerged, among many others, as a widely used approach in the development of CT, gaining relevance in the curriculum base of several educational systems around the world. Most of the studies reviewed report positive results for the use of board games as an unplugged activity in the development of CT. For example, Berland & Lee (2011), Berland & Duncan (2016), Kuo & Hsu (2020), Wu & Su, (2021) and Hsu & Liang, (2021) observe players' behaviour to subsequently code their interactions based on CT dimensions. This type of approach corroborates Wing's (2006) argument that "Computational thinking involves solving problems, designing systems, and understanding human behaviour (p. 33)". Wu & Su (2021) suggest a symbiosis between board game design and game mechanics: "the design of a tabletop game should consider how the content of the game is matched with the game mechanics" (p. 1).

Indeed, studies such as those by Apostolellis *et al.* (2014), Tsarava *et al.* (2018) and Wangenheim *et al.* (2019) describe in detail the design process of board games specifically created for the development of CT skills in primary school students. Some studies report pilot tests conducted with students of varied age groups, reporting positive results on the game experience, fruit of thought mechanics and created to develop this skill. Ten years earlier, Berland & Lee (2011) had already advocated the cognitive benefits of board game mechanics, especially the contemporary, modern German-style games, in which resource management, limited game times, engaging themes, reduced randomness, no dependence on the luck factor, constant participation (without eliminating players) and the encouragement of direct interaction with peers should be considered in the design of a board game. The authors used the game Pandemic, assuming its collaborative typology, without ever referring to this board game as a modern board game or a Eurogame. This can perhaps be explained in the argument advanced by Rogerson & Gibbs (2018) that it is usually the players who adopt board games as a "Hobby" and who refer to a board game as modern to differentiate it from more conventional board games. On the other hand, as stated by Sousa & Bernardo (2019), defining a board game as modern is not an easy task, and the taxonomy created by these authors allows us to catalogue the game used by Berland & Lee (2011) as a modern board game, incorporated in the subgenre Eurogame. Collaborative board games are usually used to develop CT, as they allow for the externalisation of the procedural and collaborative thinking implicit in their actions, thus enabling explicit verbalisation of computational reasoning (Berland & Lee, 2011; Kuo & Hsu, 2020).

However, the use of modern non-collaborative board games should not be disregarded, as according to Berland & Lee (2011) "we expect similar computational processes also take place in non-collaborative strategic board game play (p. 78)". Hsu & Liang's (2021) study suggests the possibility of linking board games to educational robotics to promote CT skills, envisaging benefits in the early introduction of plugged and unplugged approaches, as stated by Brackmann *et al.*, (2017): "some studies are already merging the two approaches and allowing the students to migrate from unplugged to plugged activities at a smoother pace" (p.8). Finally, scaffolding techniques or instructional design may constitute an important step towards implementing activities of this nature in a classroom context to support the student in understanding more complex rules associated with new modern board games.

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