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SYSTEMATIC REVIEW

Students' development of Computational Thinking and Teachers' professional development via Bebras through Gamification: A systematic literature review

Desarrollo del Pensamiento Computacional de los Estudiantes y Desarrollo Profesional de los Profesores a través de Bebras mediante Gamificación: Una revisión sistemática de la literatura

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ABSTRACT

The Bebras Challenge is an international initiative that promotes computational thinking among students through fun and engaging challenges. It incorporates gamification elements, which play a significant role in making learning more interactive and motivating. For teachers, it offers valuable professional development opportunities, helping them to incorporate these concepts into their teaching practices. However, so far, a limited number of studies have been conducted to investigate Bebras Educational Competition and Gamification for the development of students' computational thinking in secondary education. Also, while the Bebras Challenge is widely recognized for its role in promoting computational thinking through engaging tasks, the specific intersection of Bebras, gamification, and teacher development is a relatively underexplored research area. Specifically, for this paper seven databases were searched, and 33 papers were finally selected for this review. The findings seem to shed light on whether Bebras competition might enhance the development of students' computational thinking, and to present what could be the potential impact and effectiveness of a gamified learning approach included in Bebras initiative for promoting computational thinking skills among students, especially in secondary education. A significant conclusion stemming from findings of this review, is that the learning of teachers at a professional level, and the development of their expertise, leads them to changes in teaching practices that have as a final result the improvement of student learning and the development of students' computational thinking skills.

Keywords: Computational Thinking; Bebras Challenge; Gamification; Review.

RESUMEN

El Desafío Bebras es una iniciativa internacional que promueve el pensamiento computacional entre los estudiantes a través de retos divertidos y atractivos. Incorpora elementos de gamificación, que desempeñan un papel importante a la hora de hacer el aprendizaje más interactivo y motivador. Para los profesores, ofrece valiosas oportunidades de desarrollo profesional, ayudándoles a incorporar estos conceptos a sus prácticas docentes. Sin embargo, hasta ahora, se ha realizado un número limitado de estudios para investigar la Competición Educativa Bebras y la Gamificación para el desarrollo del pensamiento computacional de los estudiantes en la educación secundaria. Además, mientras que el Desafío Bebras es ampliamente reconocido por su papel en la promoción del pensamiento computacional a través de tareas atractivas, la intersección específica de Bebras, la gamificación y el desarrollo del profesorado es un área de investigación relativamente poco explorada. En concreto, para este trabajo se realizaron búsquedas en siete bases de datos, y finalmente

se seleccionaron 33 artículos para esta revisión. Los resultados parecen arrojar luz sobre si la competición Bebras podría mejorar el desarrollo del pensamiento computacional de los estudiantes, y presentar lo que podría ser el impacto potencial y la eficacia de un enfoque de aprendizaje gamificado incluido en la iniciativa Bebras para promover las habilidades de pensamiento computacional entre los estudiantes, especialmente en la educación secundaria. Una conclusión significativa que se deriva de los resultados de esta revisión, es que el aprendizaje de los profesores a nivel profesional, y el desarrollo de su experiencia, les lleva a cambios en las prácticas de enseñanza que tienen como resultado final la mejora del aprendizaje de los estudiantes y el desarrollo de las habilidades de pensamiento computacional de los estudiantes.

Palabras clave: Pensamiento Computacional; Desafío Bebras; Gamificación; Revisión.

INTRODUCTION

Over the past decade, the idea of cultivating computational skills as a set of abilities with universal value and power for every child has garnered much research interest, while key questions are emerging about how to integrate Computational Thinking (CT) into formal curricula. Furthermore, another important issue concerns the level of readiness and teachers' ability to teach and promote CT skills by integrating them into their curriculum and subject matter object.[1,2]

CT and the clarification of its related skills is necessary and critical for its proper and effective integration into education and specifically into the formal curriculum. At the same time, as the applications related to the concept of formal or informal educational context are increasing, great emphasis and attention is given to the selection of cognitive and scientific subjects of compulsory education that would be suitable for its integration. Highlighting all the critical factors likely to influence the cultivation of CT skills in the context of compulsory education, as well as illustrating the trend and integration initiatives in each country, can be made clearer if information and up-to-date data are collected from the responsible and those involved with these initiatives.[1,3,4]

There are several educational actions, formal or informal, such as educational competitions that are implemented at national and international level with the aim of integrating CT skills in education and are worth mentioning. In addition, emphasis should be placed on secondary education, since the framework it provides is suitable for achieving the above goals.[5,6] From the "CompuThink" survey of the European Commission for Science and Knowledge, designed and financed by the European Commission's Research Center, and launched in 2015, data emerge that reveal the current situation and the degree of development of the efforts of various countries in Europe (also Turkey and Israel) to incorporate CT into their curriculum. The ultimate goal is to provide a comprehensive overview of initiatives to develop CT as a 21st century skill in primary and secondary school students, as well as the implications this will have at a political and practical level.[5,6]

This article based on relevant publications in literature, aims to contribute to a better understanding of competitions and specifically Bebras competition, which is organized and carried out to cover all primary and secondary education. The main purpose of Bebras competition is to provide students learning and motivational stimuli to utilize Information Technology and help them to develop a computational thinking skillset. Thus, a systematic literature review on Bebras is conducted that involves a comprehensive and structured analysis of existing research studies, articles, and publications related to the initiative. Through this systematic approach, a literature review on Bebras initiative might provide valuable insights into the impact and effectiveness of the initiative in promoting computational thinking skills among students, as well as identify the key factors influencing teachers' development of skills and strategies to effectively integrate gamification in teaching computational thinking to students and identify gaps in the existing research and area for future investigation.

Background

Gamification utilization for Developing Computational Thinking in High School Students

Computational Thinking (CT) is a fundamental skill that involves problem-solving using concepts and techniques from computer science. CT includes logical reasoning, pattern recognition, abstraction, and algorithmic thinking, which are crucial for success in the digital age. Integrating gamification into educational settings is a growing trend to enhance learning experiences and develop CT skills. Gamification in education, particularly for developing computational thinking, is supported by both theoretical and empirical research. Specifically, in the Constructivist Learning Theory, Lev Vygotsky and Jean Piaget emphasized active learning and social interaction.[7] Gamification aligns with constructivist principles by promoting active engagement and collaborative learning. Also, the self-determination theory proposed by Deci and Ryan, suggests that people are motivated to grow and change by three innate and universal psychological needs: competence, autonomy, and relatedness.[8,29] Gamification elements like points, badges, and leaderboards cater to these needs, enhancing intrinsic motivation. Additionally, the Flow Theory, introduced by Mihaly Csikszentmihalyi, describes a state of

deep immersion and optimal experience.[9] Gamification aims to create flow by balancing task difficulty and skill level, maintaining student engagement. Caponetto et al.[10] reviewed gamification in education, highlighting its potential to improve learning outcomes through increased engagement and motivation. They noted the importance of aligning game mechanics with educational objectives. Werbach and Hunter[11] discussed how gamification elements like challenges and feedback can foster problem-solving skills essential for CT. Also, Kafai and Burke[12] emphasized the role of game design in learning, stating that creating games helps students develop CT skills by applying programming concepts and logical thinking. Furthermore, Lye and Koh,[13] reviewed studies on CT in K-12 education, noting that gamification and game-based learning can effectively promote CT by engaging students in interactive and meaningful problem-solving tasks. Thus, gamification seems to enhance student engagement, motivation, and learning outcomes by incorporating game design elements that cater to intrinsic psychological needs and create an optimal learning environment.[67] By aligning gamification with educational objectives, educators could effectively develop CT skills in high school students.

Computational Thinking Integration efforts for Compulsory Education

The general trend prevailing in compulsory education includes the introduction of Computer Science, in the form of Computational Thinking (CT), programming and digital skills in primary education, while for secondary education, emphasis is placed on the development of broader IT courses, in relation to the impact that has the cultivation of its skills in society.[3,4,5,6,14] In many countries, this is done or is planned to be done, by integrating the requirements into the already existing teaching program and into the existing teaching subjects, while emphasizing and exploiting the interdisciplinary nature of the field. There are also countries that have included computing as a separate subject. Although approaches and strategies vary, the general trend of modern education tends to place more and more importance on computational skills from primary and secondary education.[6,15]

In a brief presentation, two general axes could be distinguished, based on which the logic of their inclusion in compulsory education is developed. According to the first, the development of CT skills by children and young people will support a new way of thinking and expressing oneself, solving real problems and analyzing everyday issues. While, according to the second, the promotion of CT aims to stimulate economic development, fill Information and Communication Technology (ICT) jobs and prepare for future employment. Although the emphasis given by each country, inside and outside Europe, to CT differs, the main, overall, reason for introducing it into education is the cultivation of the necessary cognitive, social and professional skills in the modern digital age of the 21st century.[6]

From the *CompuThink* survey completed in 2016, three groups emerge into which the participating countries can be included, according to the level at which the developments in the requested field are [5,6]. These in brief are:

- 1st group: Countries in which, in the last three to five years, a process of revision and restructuring of the curriculum has been initiated, with actions not limited to upgrading the curriculum, but including changes in teaching, learning and assessment, as well as in the school organization. These are: England, France, Finland, Poland, Italy, Turkey, Denmark, Portugal, Malta, Croatia and Scotland.
- 2nd group: This includes countries that have not yet introduced CT into compulsory education but are preparing to do so soon. These are: Czech Republic, Ireland, Norway, Wales, Greece, Netherlands, and Sweden.
- 3rd group: It consists of the countries that build a long tradition of IT in education, focusing on secondary education. The main trend that characterizes this group is the expansion of education in Computer Science to the lower levels of education, primary and early secondary, while CT plays a central role in this perspective. These countries are: Austria, Cyprus, Israel, Lithuania, Hungary and Slovakia.

In some countries that do not appear in any of the above groups, curricula are developed regionally, such as in Spain, Belgium, Germany and Switzerland, so the integration of CT varies from region to region.

For Greece, from the data of relative conducted research in the field, it emerged that there was the prospect of integration into the study programs in primary and secondary education as an immediate priority, with the proposal being introduced from the first grades of Primary School to the last grade of High School.

In more detail, in the Report of the Committee on Educational Affairs and the timetable of proposals and solutions, the need to create an "*information culture*" that will keep pace with the needs of the modern era is highlighted, while specifically for CT it is stated that alongside the basic skills that must be mastered by each student, it can favor their personal, intellectual and social development as well as the economic development and well-being of the environment in which they live and work. Therefore, it is suggested that it be included in the education from the beginning of the first grade. It is even characterized as "*a philosophy of dealing with the challenges of society that is applied to all kinds of problematic and reasoning*". Thus, its integration into the system is placed among the short-term priorities of the schedule, with the overall goal of the country's

education system keeping pace and harmonizing with international policies and practices.[16]

Non-standard promotional initiatives of Computational Thinking

Apart from the official tendency to integrate CT into the curricula of each country, there are many non-formal structures and initiatives that operate and are implemented in parallel, with the same purpose, without being part of formal education, although they have the power to affect it. The informal, unofficial initiatives include groups (clubs), such as Coder Dojo and Code Club, whose main objective is to introduce programming to children, in a friendly and motivated environment, Olympiads and competitions, such as Bebras, the Robo Cup Junior and the Informatics Kangaroo, and the outreach programs or projects of various local or wider organizations and companies, such as Teaching London Computing, Barefoot Programme, CS Unplugged, Computational Thinking Toolkit (ISTE-CSTA), Google SC First, Kodcentrum and others.[17,18] Listed below are the most important of them (see table 1), at European and global level, which are very often used in research work in the field, together with their brief descriptions, as well as the official websites for each, from which useful information was collected.[6,19]

Table 1. Computational Thinking integration initiatives

Initiatives on a global scale
Code.org: Non-profit organization since 2013, expanding access to computer science in schools and increasing the participation of women and minorities. More than 39 million students have used Code Studio. It also organizes the Hour of Code, with more than 180 countries and 220 000 actions in 2018. Official website: https://code.org/
CoderDojo: Community of 1773 free, open and local programming clubs (dojos) for young people, 7-17 years old, running after school, led by volunteers (12 000), in 94 countries in the world reaching 58 000 children. Kids, parents, mentors and others play with technology and learn to code. Official website: https://coderdojo.com
Bebras: International initiative, since 2004, to promote computer science and Computational Thinking among educators, students and the public, with annual student competitions in over 50 countries. For the first time, implementation of the pilot competition in Greece, in 2019. Official website: www.bebras.org and www.bebras.gr for Greece.
CS Unplugged: Collection of free teaching materials for IT education through engaging games, puzzles, flashcards, coloring and more, without the need to use a computer or know how to program. Many connections to Computational Thinking in the activities. Official website: https://csunplugged.org/en/
Code club: Global network since 2012, 13 000 active, free coding clubs for children aged 9-13 (180 000), in 160 countries. Official website: https://codeclub.org/en/
Made with Code: Google-funded initiative to get girls into programming and close the gender gap in technology. Provides resources, motivation, videos and programming activities. Official website: https://www.madewithcode.com/
Computational Thinking Toolkit: Comprehensive collection of Computational Thinking resources from ISTE and Computer Science Teachers Association (CSTA) that include complete Computational Thinking learning experiences and learning scenarios to support educators.
Initiatives at European level
CodeWeek: Initiative, since 2013, aiming to promote code and digital literacy to everyone in a fun way. In 2017, 1,2 million people in more than 50 countries around the world participated in code week. Official website: https://codeweek.eu/
All you need is code: A multi-stakeholder European Coding Initiative to promote coding and Computational Thinking at all levels of education, and in informal settings. It was created in 2014 under the auspices of the European Commission. Official website: http://www.allyouneediscode.eu/
CAS Barefoot: Launched in 2014, to support the UK teachers in implementing the IT curriculum. It empowers teachers with the confidence, knowledge, skills and resources to help students become 'computational thinkers'. At the end of 2018, the community numbered over 2 million children and 70 000 teachers. Official website: https://www.barefootcomputing.org/
Computing at School: It provides guidance to all those involved in IT education in schools, with a particular focus on the IT area of the curriculum. It has more than 32 000 members, mainly UK teachers. Official website: https://www.computingatschool.org.uk/

In addition to the above, several other ways are found in the contemporary bibliography, which although not exclusively dedicated or connected to the promotion of Computational Thinking and computational skills in education, can be used to help this aim and support teachers in teaching necessary problem-solving skills, within and outside the compulsory school curriculum.

One of them is the use of '*Scratch*', which enables users to program their own interactive stories, games and animations and share them with the online community. It can thus help students, in an easy-to-use environment, think creatively, reason methodically and collaborate, facilitating the development of Computational Thinking. Scratch, according to recent information from its official website (https://scratch.

mit.edu/), is used in more than 150 different countries and is available in more than 40 languages.[20]

Another context worth mentioning is that of educational robotics. Educational robotics is being introduced in many schools as an innovative learning subject, enhancing and leveraging thinking skills and abilities, helping students to solve complex problems. Furthermore, with their appropriate support in the use of robots, teamwork is enhanced, conceptual understanding is improved, and critical thinking is fostered, while at the same time, more specialized learning in sciences such as Mathematics and Physics is promoted. Robotics activities help children transform from passive to active learners and develop basic intellectual skills by acting as researchers. In this context, robotics can be used as a tool that offers opportunities for students to cultivate Computational Thinking. In many researches it is even reported that through students' engagement with it, they can develop and apply basic skills, such as abstraction, automation, decomposition and others.[21]

Of course, the initiatives, educational programs and various environments in which Computational Thinking can be cultivated and students' skills can be developed are not limited. With developments moving rapidly in the field of Information Technology, the field is constantly being explored in greater depth and evolving, thereby creating various connections and leading to new conclusions about ways to integrate the concept into education, formally or informally. More than 50 different tools, software, applications and games are listed in the review by Lockwood and Mooney.[22] These range from musical instruments to programming languages in games. Although many are still in early stages of development, their existence is encouraging as they provide opportunities to make Computational Thinking fun and accessible to students of all ages, genders and abilities. At the same time, the benefits for teachers are many, since they are provided with a multitude of options to incorporate the concept into their teaching, whether this is done in a computer lab, in a typical classroom or outside the school, on a group or individual level, thus serving the most from their needs.[21,23,24,25,26,27]

Educational Competitions

As it can be seen, the promotion of Computational Thinking does not depend only on its integration into the formal curriculum but finds a variety of ways and appropriate environments to achieve it. One of the most important points is to provoke and maintain the interest of those involved in it, students and teachers, in such a way as to activate intrinsic learning motivation and create a positive attitude both towards Computational Thinking and its dimensions, as well as towards in the broader field of computer science.[6,19,27,28]

In order to stimulate the thinking process of each student, various means are needed. Gamification could be a driver for student engagement in IT learning as well as an engaging tool to introduce scientific concepts in a playful and entertaining way.[27,67] An educational competition with these characteristics could serve as an educational tool to promote meaningful learning. Solving challenging tasks during a competition can be considered as one of the effective tools for activating thinking and, by extension, the learning process. Although contest topics do not usually function as instructional tools, they have the power to be used for this purpose.[30]

IT competitions can be a key to new knowledge, as they are an attractive way of engaging technology with education, playing an important role as a source of innovation and inspiration. They can lead students to an understanding of computer science, making teaching its subjects more engaging. At the same time, they can respond to students' need to show and evaluate their abilities, share their interests and socialize or even compare with other students, creating friendships and motivation to learn at the same time.[30]

In fact, apart from the effect that a competition can have on students, if it manages to be a pleasant experience for the participating teachers, then it can give them the necessary encouragement to adopt CT in their teaching program, which will result from their intrinsic motivation and not from the mandatory nature that can have, for example, a mandated curriculum.[31]

There are many IT competitions held annually. Since 1989, Computer Science has been one of the scientific fields, along with Mathematics, Physics, Chemistry and others, in which there is an "*Olympiad*" for high school students, a competition aimed at the best students in each subject. In other competitions, the facts are different. Of course, in any case, the primary purpose of all is to attract students to the field and influence them to engage more deeply in it in the future. To achieve this, competitions should focus on changing the habitual negative attitude students have towards the subject matter, due to their mistaken view of their limited abilities in it.[6,19]

Bebras Competition

The International Bebras Challenge on Informatics is an annual international initiative aiming to promote computational thinking among students of all ages.[30,32,33,34,35] It was founded by the University of Vilnius and first administered in Lithuania in 2004. Particularly, Bebras is a global initiative that aims to promote computational thinking among students of all ages. Computational thinking involves problem-solving and

critical thinking skills that are essential for understanding and solving complex problems, not just in computer science but in various fields. Bebras provides a series of challenges and competitions designed to engage students in computational thinking activities. These challenges typically involve puzzles, logic problems, and algorithmic thinking tasks that require participants to break down problems into smaller steps, analyze patterns, and devise efficient solutions.[36] Also, Bebras provides a valuable platform for educators to incorporate computational thinking into their curriculum in an enjoyable and accessible manner, helping students develop essential skills for the digital age.[36] The highly popular competition, first started in Lithuania, in October 2004, with 3 470 participants from 146 schools and has progressed since then with a particularly upward course over time, reaching the number of 523 319 participants from 21 countries in 2013.[37] Its story actually began a little earlier, in September of the same year in Lithuania, when an experimental test was carried out, with 779 participating students, while a preparatory period of about a year was needed to create the subjects and prepare the necessary technological means for its application. The original name of the competition arose during a trip of its creators to Finland in 2003, a special point of which was the observation of the characteristic and intense activity of beavers on the branches. The persistence in achieving a goal, the pursuit of perfection, the intelligence, hard work and vitality that characterize these animals, were the trigger for choosing the name of the competition.[32] Thus, the competition acquired the name "Bebras". The name is either adopted as is in its basic form, as for example in Italy, Azerbaijan, Iran, Spain, Taiwan, Ireland, the United States, etc., or is transferred to the official language of the respective country participating in the competition. Thus, it appears as '*bebras*' in its original form or as '*kobras*' in Estonia, '*majava*' in Finland, "*castor*" in France, "*biber*" in Germany, "*dabar*" in Serbia, "*borb*" in Slovakia, "*bilge kunduz*" in Turkey, etc. according to each translation. The idea for the competition was born by Vilnius University professor Valentina Dagiene, whose goal was to establish the competition as an international initiative for IT in schools. Since 2015, the competition has evolved, now being a challenge for Informatics and Computational Thinking and was renamed "*Bebras challenge on informatics and computational thinking*".[32,34,35] The initial goal began to be achieved with the contribution of the organization of the Baltic Olympiad in Informatics, in 2005 in Lithuania, which gave the opportunity to advertise the competition in the participating countries. During the event, the first international workshop for the creation of Bebras competition themes was organized.[32,34,35,38] In the first workshop held, it was decided that the competition would take place every autumn, between October and November. Most countries now organize the competition event in the second week of November, which has also been designated as "*Bebras Week*".[32] Some countries have also established a second competition period, at the end of January or the beginning of February, dedicated to the students who achieved the best results. Since its inception, the competition has spread and been held in many countries, such as Estonia, the Netherlands, Poland and Germany, which were the first to participate, in 2006. Shortly after, in 2007, Austria, Latvia and Slovakia made their first participation. Other European countries followed, such as the Czech Republic and Ukraine, in 2008, Italy in 2009, Finland and Switzerland in 2010 and France together with Hungary and Slovenia in 2011. In fact, the same year saw the first participation from another continent and specifically from Japan. Entries continued to rise with Bulgaria, Sweden and Taiwan in 2012. Today, the list of countries that carry out the competition continues to be enriched and extended, with countries inside and outside the European borders, while, according to the official website,[71] many more are expected to implement the competition, such as Denmark, Mexico, the Philippines, Norway, Morocco and Ivory Coast. Among the countries that have adopted the competition is Greece, for which the "*Castoras*" competition was held in 2019 as a trial, from the Learning Technology and Educational Engineering Laboratory of the University of the Aegean, and Cyprus, for which the competition is held annually from the Cyprus Computer Society and the Cyprus Ministry of Education, Sport and Youth.[39] The number of participants worldwide is rapidly increasing, with approximately 1 000 000 students from 34 countries, in 2014, more than 1 313 000 students and 38 countries in 2015, more than 1 610 000 students in 2016, while it exceeded 2 660 000 students in 2017, with participation from 44 countries.[32] As can be seen from the 2017 participation statistics, there were typically numerous participations, such as France with 598 869 participants, Germany with 341 241, the United Kingdom with 143 134 and Ukraine with 117 463.

The Bebras Organizing Committee was established during the second official meeting of the international workshop, which took place in 2006. The management mechanism of the Bebras Challenge consists of three main bodies at national and international level: the National Bebras Organizations (National Bebras Organisations-NBO), the International Bebras Community (International Bebras Community- IBC) and the Bebras Board (Bebras Board-BB). The International Organizations are responsible for a variety of activities, such as submitting new topics, selecting and translating, organizing the competition, training teachers, and producing educational and promotional materials. There is a possibility for the establishment of only one National Organization in each country participating in the competition. Representatives of these Organizations are the International Committee (International Bebras Committee), of which they are considered members at every annual meeting, while only one member of each mission has the right to vote, when taking decisions of

the Community. Finally, the Competition Council is the executive body of the Community and is responsible for all ongoing work aimed at supporting, evaluating and providing feedback to the community. Members of the Community are the organizations responsible for the organization of Bebras at the national level.[40] In addition, for the effective management and implementation of Bebras, many countries, such as Estonia, France, Indonesia, Poland, Russia, Serbia, the Netherlands, etc., have proceeded to create various management systems (contest/ challenge management systems-CMS).[34]

The workshops for the development of the topics of the competition to follow are held every spring, with the main objective of creating a group of suitable topics, their processing, but also the interaction and cooperation, in order to achieve understanding and agreement between the members, which come from different countries and therefore represent different educational programs and educational habits, both in Information Science and in general education.

The general purposes, around which the competition started to be organized and carried out, are: (i) To give students motivational stimuli to increase their interest in Information Technology, (ii) To highlight the variety of subjects and concepts of Informatics, (iii) To highlight the interest and challenge involved in solving IT problems, (iv) To provide learning stimuli, and (v) To support positive attitudes towards IT.[35,38]

Scope of paper

One of the key aspects of Bebras is its gamified approach to learning. By presenting computational concepts in a fun and interactive way, Bebras might help students develop a deeper understanding of fundamental principles in computer science and related fields. The challenges vary in difficulty and cover a wide range of topics, ensuring that participants can continuously challenge themselves and improve their skills.[30,34,35,40] So far, the gamified approach of Bebras to learning has not been investigated seriously to get a deeper understanding of how this new learning approach could help to better learning outcomes for the benefit of students. Specifically, Ramírez de Arellano Falcón et al. in their study entitled as "*Is gamification always productive? A study of the effectiveness of Bebras cards in promoting primary students' computational thinking skills*", are among the first to examine how Bebras cards might be effective in enhancing students' computational thinking skills.[41] However, their research is mainly focused on primary learners and does not examine how Bebras cards might enhance the learning motivation of students in secondary education. Hence, there is a research gap that needs to be investigated and new findings to be added to the existing literature. Specifically, Ramírez de Arellano Falcón et al. have run an intervention utilizing Junior School Bebras Cards, that is an unplugged learning material without the use of technology, that is offered by UK Bebras.[41] Their outcomes suggested that Junior Bebras Cards seems to be a promising solution for the development of students' computational thinking skills. However, they stated that gamification after using Junior Bebras Cards did not lead to remarkable learning progress. Students' learning motivation was not enhanced significantly as it was initially expected.[41] Thus, finding new pathways of utilizing key aspects of Bebras with the use of a new gamified learning approach seems a very interesting challenge for research.

The purpose of conducting a systematic literature review is to identify existing research and knowledge gaps. Specifically the main objective is to consolidate and summarize existing research on how the Bebras initiative and gamification techniques contribute to: (i) students' development of Computational Thinking skills, (ii) provide effective methods for incorporating computational thinking into classroom activities using gamification, (iii) identify the key factors influencing teachers' development of skills and strategies to effectively integrate gamification in teaching computational thinking to students, and (iv) create a foundation for future research by synthesizing findings and identifying methodologies, tools, and frameworks that have been effective for both students' and teachers'.

METHOD

This review tries to answer the following basic research questions:

RQ1. Does Bebras competition enhance the development of students' computational thinking?

RQ2. What is the impact and effectiveness of a gamified learning approach included in Bebras initiative for promoting computational thinking skills among students?

RQ 3. What are the key factors influencing teachers' development of skills and strategies to effectively integrate gamification in teaching computational thinking to students?

Search strategy of academic databases

A systematic literature review on Bebras would involve a comprehensive and structured analysis of existing publications related to the initiative. To develop a search strategy and identify relevant studies, a search was conducted in the following 7 academic databases: Scopus, ACM Digital Library, Emerald Insight, IEEE Xplore, JSTOR, Springer Link, and Science Direct using the keywords: "*Bebras*", "*gamification*", and/or "*computational thinking*", and/or "*problem-solving*".

To select some necessary publications for our systematic literature review, we defined the following criteria:

- Search for eligible publications focusing on gamification, bebras and the development of CT of middle schoolers.
- Full-text papers written in English language.
- Peer-reviewed full-text papers that focused on Bebras competion and Bebras learning material (plugged or unplugged) and gamified learning approaches for the development of CT were selected for review.
- Research-selected papers, where there was a detailed description of existing gamification background (e.g. gamfied learning approach, game mechanics, game elements) were selected for review.
- Research methods in the papers are clearly explained.

Scopus database search

A detailed search in the Scopus database was run to find Scopus indexed documents on Bebras educational competition and gamification for the development of students' computational thinking, published from 2004-2024* (the 2024 data refer to May 2024). The database of Scopus was queried using the following search string: *TITLE-ABS-KEY (bebras AND computational AND thinking AND gamification) AND PUBYEAR >2004* (a search in the field including titles, abstracts, and keywords in the Scopus database, accessed May 04, 2024). After the search only one document was identified which was the following: "*Is gamification always productive? A study of the effectiveness of bebras cards in promoting primary students' computational thinking skills.*".[41] The authors decided to run several searches in the Scopus database in order to find eligible documents for this review. In the last search by using the following search string: *TITLE-ABS-KEY (bebras) AND PUBYEAR >2004* (a search in the field including titles, abstracts, and keywords in the Scopus database, accessed May 04, 2024),164 documents were identified including 112 Conference Papers (67,1 %), 30 Articles (18,3 %), 20 Conference Reviews (13,4 %), and 2 Book Chapters (1,2 %). The Scopus database included a suite of metrics to help analyze the published documents. Thus, through the analysis the following findings emerged:

Of 164 documents initially found in Scopus database, in the main subject areas of published documents, Computer Science accounted for 47,9 %, Mathematics accounted for 20,8 %, Social Sciences accounted for 20,8 %, Business, Management and Accounting accounted for 4,5 %, Engineering accounted for 2,8 %, Decision Sciences accounted for 1,7 %, Energy accounted for 0,3 %, Environmental Science accounted for 0,3 %, Physics and Astronomy accounted for 0,3 %, and Psychology accounted for 0,3 % (see figure 1).

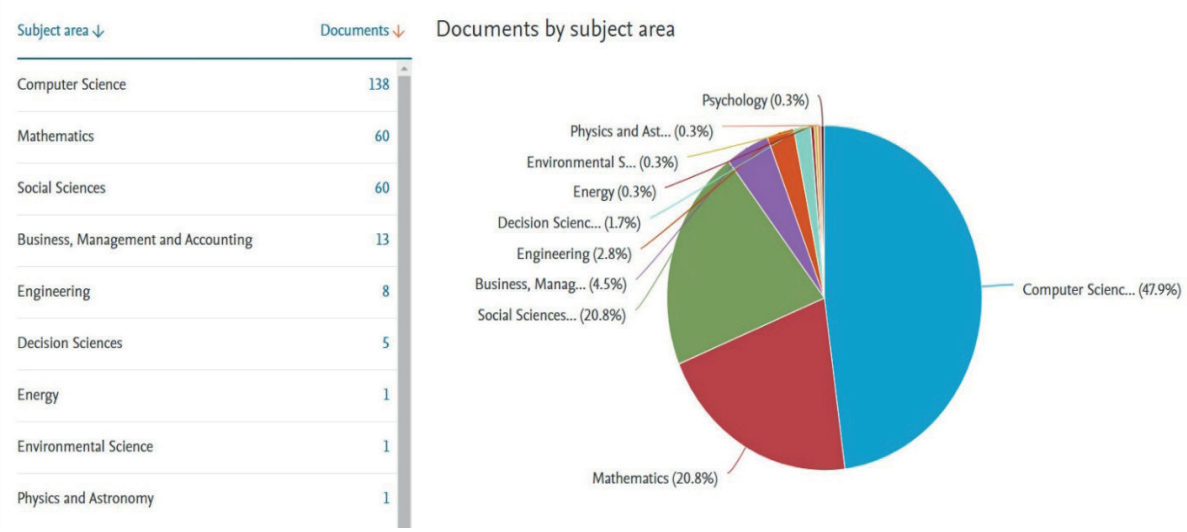

Figure 1. Scopus-indexed documents by subject area

Regarding the publications by year coming from the search in Scopus database we have: 1 publication in 2008, 0 publications in 2009, 2 publications in 2010, 3 publications in 2011, 0 publications in 2012, 7 publications in 2013, 8 publications in 2014, 8 publications in 2015, 15 publications in 2016, 14 publications in 2017, 19 publications in 2018, 16 publications in 2019, 17 publications in 2020, 11 publications in 2021, 19 publications in 2022, 22 publications in 2023, and 2 publications in 2024 (the 2024 data are incomplete so far) (see figure 2).

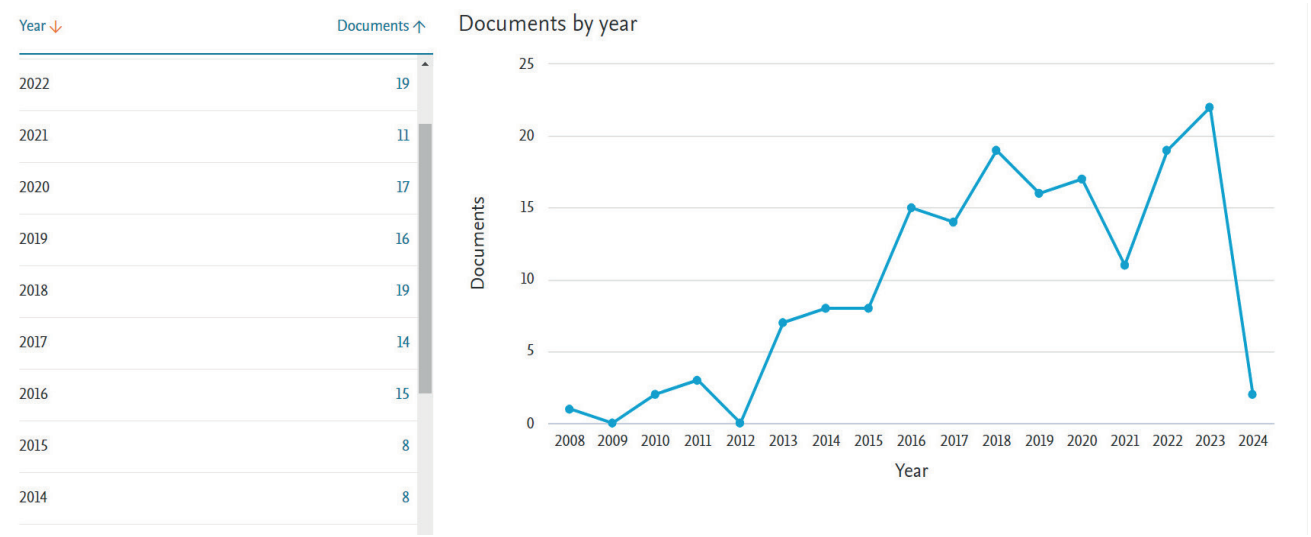

Figure 2. Scopus-indexed documents by year
Note: the 2024 data refer to May 2024.

As for affiliations (see figure 3), the following universities and institutions had the highest rank, with 25 documents from Vilniaus Universitetas; 15 documents from Università degli Studi di Milano; 12 documents from Univerzita Komenského v Bratislave; 8 documents from Jihočeská univerzita v Českých Budějovicích; 6 documents from Technische Universität München; 5 documents from Maynooth University; 4 documents from Eötvös Loránd Tudományegyetem; 4 documents from Windesheim University of Applied Sciences; 3 documents from the Royal Institute of Technology KTH; 3 documents from the Universidade Federal de Campina Grande; 3 documents from Linköpings universitet; and 3 documents from the Tampere University.

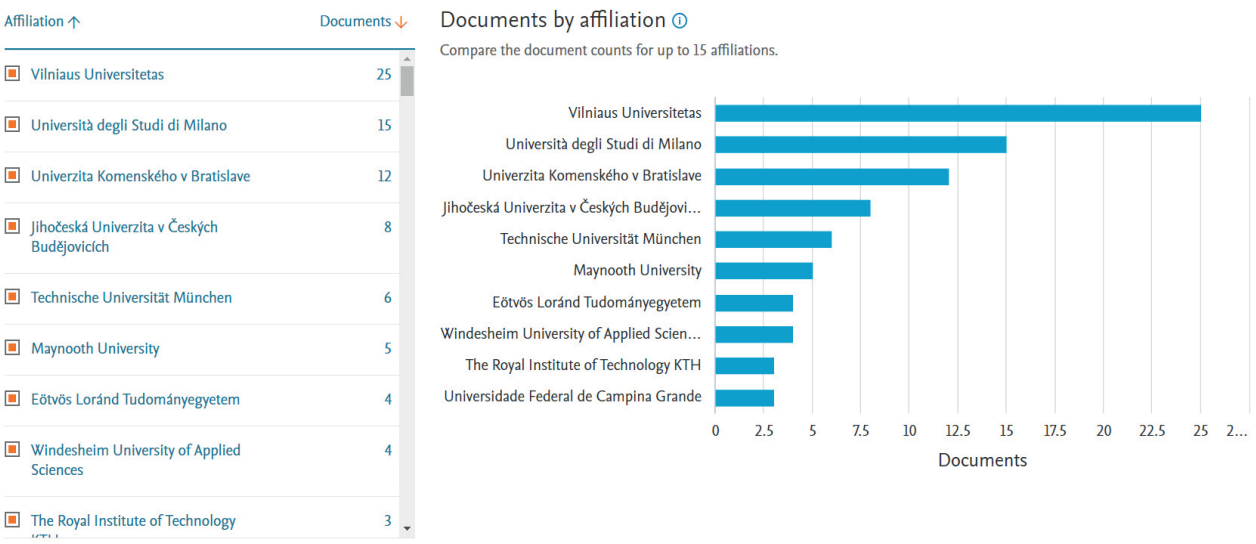

Figure 3. Scopus-indexed documents by affiliation

Also, after searching for documents per year by source (see figure 4), of 164 documents initially found in Scopus database, the bigger number of papers was published to the following source with descending order: 52 documents were published in *Lecture Notes in Computer Science including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics*, 14 in *ACM International Conference Proceeding Series*, 8 in *Informatics in Education Journal*, 7 in *Proceedings Frontiers in Education Conference*, 5 in *Ceur Workshop Proceedings*, 5 in *Education And Information Technologies journal*, 4 in *Communications In Computer And Information Science book series*, 4 documents in *IFIP Advances In Information And Communication Technology book series*, 1 document in *Acta Polytechnica Hungarica*, 1 document in *Advances In Intelligent Systems And Computing book series*, 1 in *Asia Pacific Education Review* journal, and 1 in *Computers journal*.

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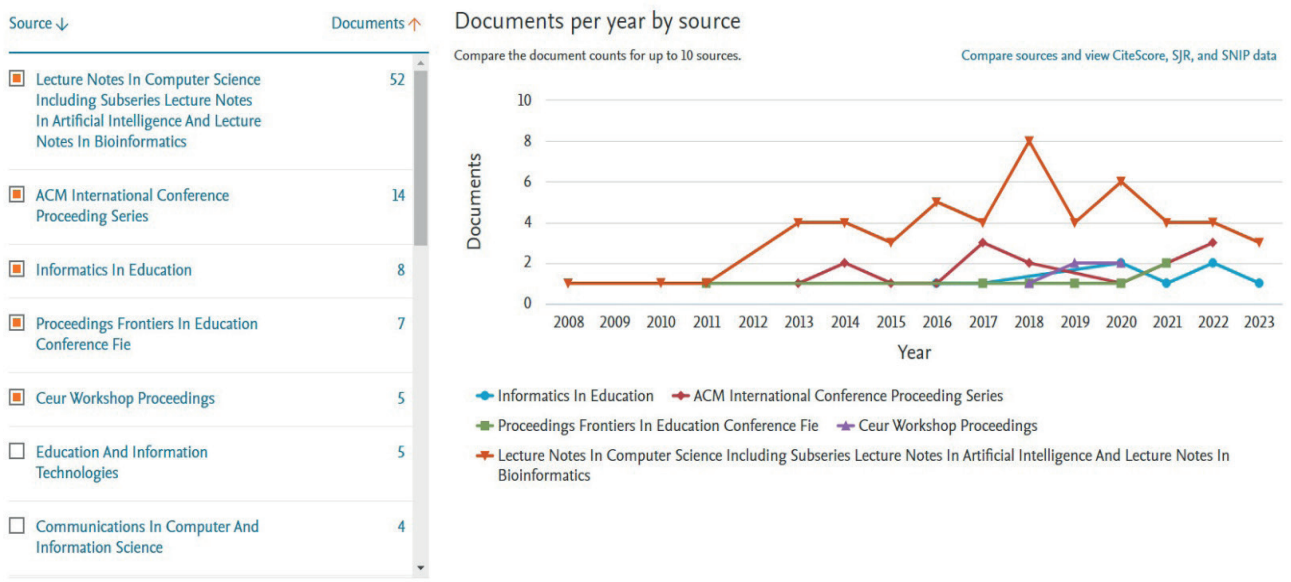

Figure 4. Scopus-indexed documents per year by source

ACM Digital Library database search: A detailed search in the ACM database was conducted to find indexed documents on Bebras educational competition and gamification for the development of students' computational thinking, published from 2004-2024* (the 2024 data refer to May 2024). The database was queried using the following search string: *[All: all: "bebras"] AND [All: "gamification"]* (a search in the field including titles, abstracts, and keywords in the database, accessed May 04, 2024). 16 results in English were identified since 2015 after the database search. Specifically, the 16 documents that were identified were conference papers. No duplicates were found. The main subject area of the published documents was Computer Science. Each of these documents were written in English language. Thus, 16 publications were selected for review.

IEEE Xplore search: A detailed search in the IEEE Xplore database was conducted to find indexed documents on Bebras educational competition and gamification for the development of students' computational thinking, published from 2004-2024* (the 2024 data refer to May 2024). The database was queried using the following search string: *bebras AND gamification*, but there were no results identified. Next, authors have decided to run a search by querying the database with the following string: *bebras* (a search in the field including titles, abstracts, and keywords in the IEEE Xplore database, accessed May 04, 2024). There were identified only 13 conference papers in English language since 2011, mainly in the subject areas of Computer Science and Education. No duplicates were found. Finally, these 13 conference papers were selected for review.

Emerald Insight database search: A detailed search in the Emerald Insight database was conducted to find indexed documents on Bebras educational competition and gamification for the development of students' computational thinking, published from 2004-2024* (the 2024 data refer to May 2024). The database was queried using the search string: String: *"bebras"*. There were 3 articles in English language identified after the search and referred to the subject area of Computer Science. The database was queried with the above-mentioned query string because it was not possible after using key terms like "*gamification AND computational thinking*" to find eligible documents for our review. Authors tried to run a second search by using the terms "*bebras" AND "computational thinking*". The results were 2 articles in English language that were identified in the subject area of Computer Science. Finally, the authors decided to run one more search (third search) by querying the database with the following string: *bebras AND gamfication AND problem-solving*. There were 3 articles identified in the subject area of Computer Science and these 3 papers were selected for review as the search string was closer to the research topic authors tried to investigate with this review. There were no duplicates, and all these 3 documents were written in English language.

JSTOR database search: A detailed search in the JSTOR database was conducted to find indexed documents on Bebras educational competition and gamification for the development of students' computational thinking, published from 2004-2024* (the 2024 data refer to May 2024). The database was queried at first using the search string: "*bebras" AND "gamification*" but there were no results after the first search. The authors have run a second search by using the following string: "*bebras" AND "computational thinking*". 15 publications were identified and specifically, 11 journal articles and 4 book chapters in the subject area of Education. 12 of the publications were in English language, 2 in Spanish language and 1 in German language. No duplicates were found. Finally, 12 publications were selected for review.

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Springer Link search: A detailed search in the Springer Link database was conducted to find indexed documents on Bebras educational competition and gamification for the development of students' computational thinking, published from 2004-2024* (the 2024 data refer to May 2024). The database was queried using the following search string: *"bebras" AND "gamification"*. 21 results were found since 2016, after running the search. Specifically, 6 research articles, 3 conference papers, 1 review article and 11 book chapters. The main subject areas of the publications were Education (9 publications), Computer Science (8 publications) and Engineering (4 publications). 20 of the total 21 publications were written in English language. There were not duplicates and after removing the one publication that was not written in English language authors decided that 20 papers would be selected for their review.

Science Direct search: A detailed search in the Science Direct database was conducted to find indexed documents on Bebras educational competition and gamification for the development of students' computational thinking, published from 2004-2024* (the 2024 data refer to May 2024). The database was queried using the following search string: *"bebras" AND "gamification" AND "computational thinking"*. 2 results were found since 2022, after running the search. Specifically, these 2 publications were written in English language. The main subject areas of the publications were Social Sciences (1 publication) and Psychology (1 publication). No duplicates were found. Finally, these 2 publications were selected for review.

A synopsis of the indexed papers in databases

A synopsis of findings for each database is illustrated in figure 5 and table 2.

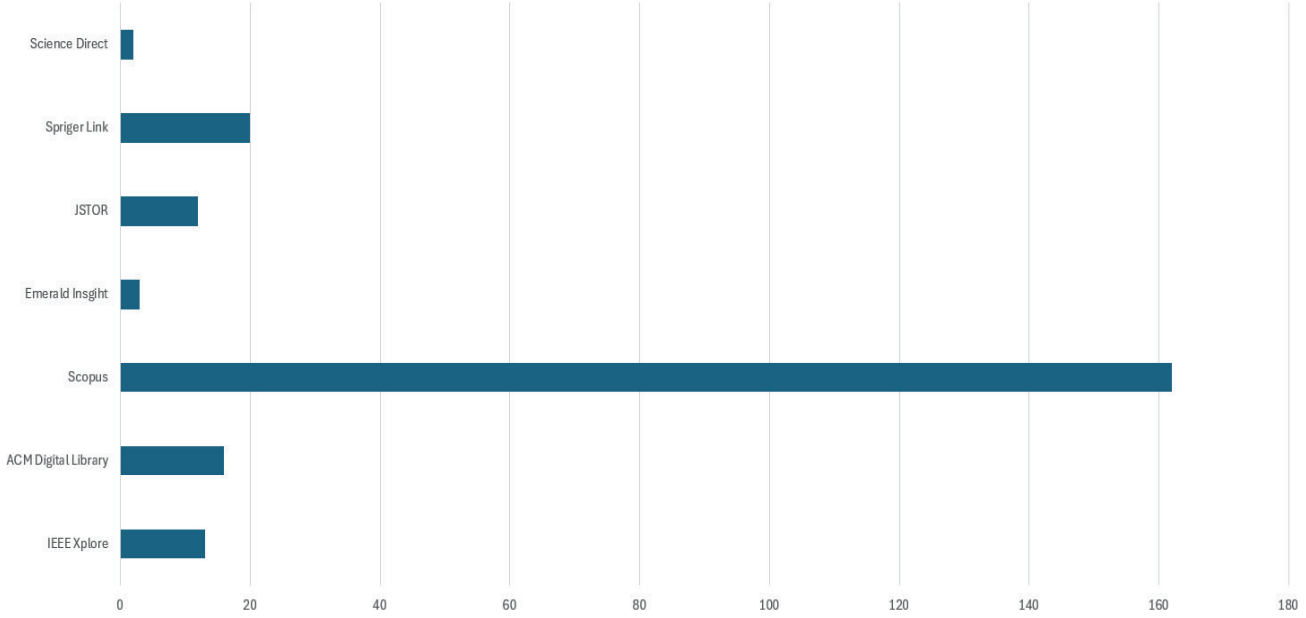

Figure 5. The Indexed papers in databases
Note. the 2024 data refer to May 2024.

Table 2. Results of indexed papers in databases

Databases	Total number of publications from 2004-2024*
Scopus	164
ACM Digital Library	16
IEEE Xplore	13
Emerald Insight	3
JSTOR	15
Springer Link	21
ScienceDirect (Elsevier)	2

Final selection of papers

After conducting the above-mentioned database searches with the criteria described above, the authors found papers with specific titles and abstracts for the subject they study. Every paper that was aligned

with the formulated criteria and rules was included in the review. For papers that it was difficult to make a straight decision after reading their title and abstract so as to select them for our review, the authors have chosen to read their full text. Finally, after conducting the searches in academic databases, 234 papers were totally found. After the screening process and the removal of duplicates, the decision for selecting 33 papers from the total number of papers initially found, lies to the fact that the authors considered that these publications are more relevant to the research topic that they investigate. Next, the authors chose to use the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) model, and specifically the PRISMA 2020 statement [42] as shown in figure 6. Specifically, in figure 6 the total records identified from 7 databases were 234. The records removed before screening were totally 11 (5 duplicate records in Scopus database were removed and 6 records contained documents not written in English (2 publications in Scopus, 1 in Springer Link and 3 in JSTOR were not written in English). The duplicates were removed via the EndNote Desktop application ("EndNote Desktop: X9 & 20: Removing Duplicates", n.d.). The records that were screened by titles and abstracts were 223. Also, 35 records were removed (20 documents after title screen and 15 documents after abstract screen) because they were unrelated to the research topic of Bebras educational competition and gamification for the development of students' computational thinking. The reports sought for retrieval were 188, the reports not retrieved were zero (0), and the final reports assessed for eligibility were 188. Of 188 documents, 37 documents with no clear research methods were excluded, 40 documents not focusing on Bebras and Gamification for computational thinking (CT) development, but with emphasis on other learning contexts, were excluded, and 78 documents that include general and not fully justified opinions based on literature about Bebras and Gamification for computational thinking (CT) development were excluded. Finally, the total number of papers selected for this review were 33 (see figure 6 and table 3).

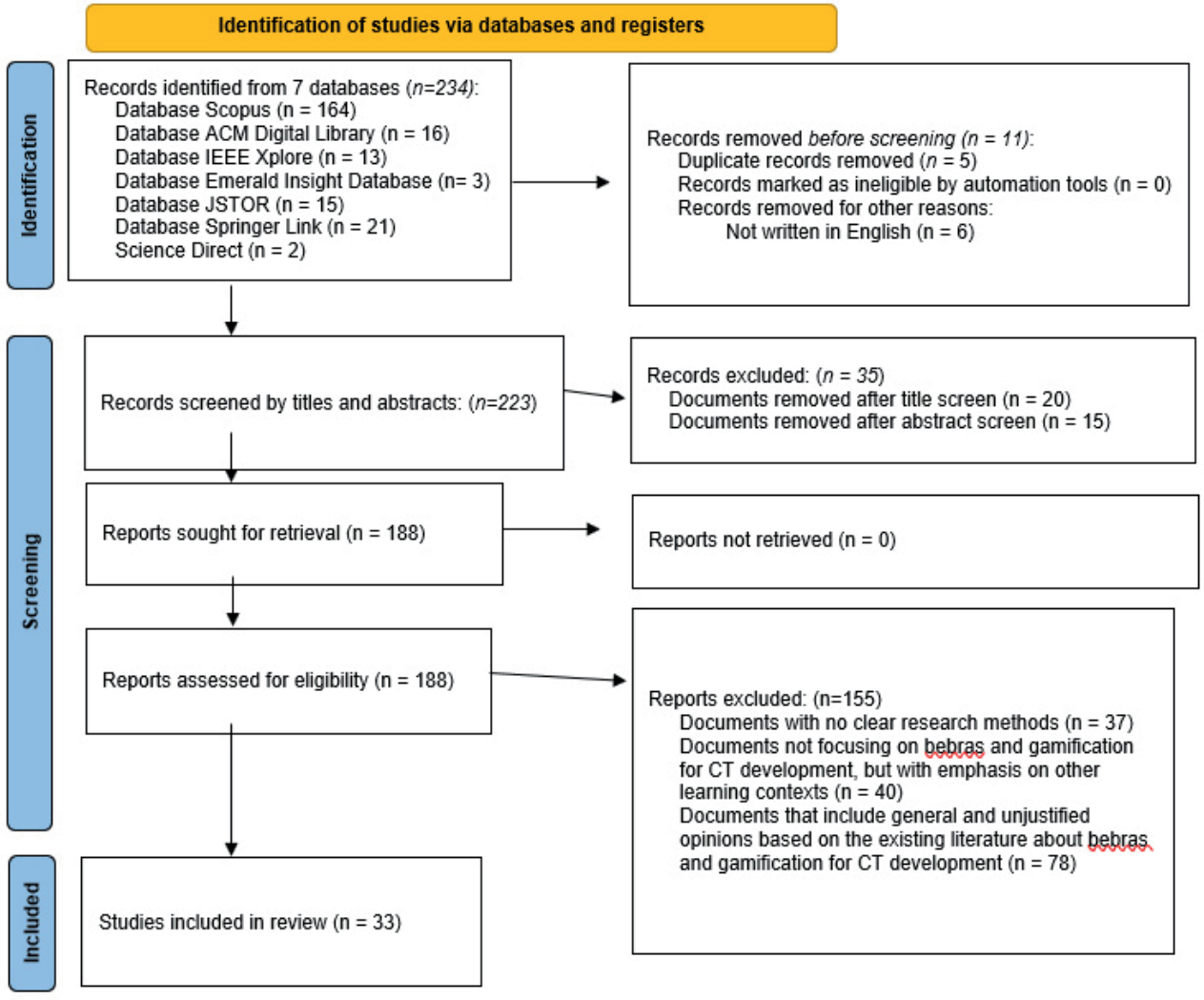

Figure 6. The PRISMA flowchart for studies selection

Table 3. Selected papers for this review

Papers type	Studies
Research articles and reviews	(17, 30, 35, 38, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 72)

RESULTS

This is one of the most basic stages of our review where we focused on giving answers to our research questions.

RQ1. Does Bebras competition enhance the development of students' computational thinking?

The Bebras competition, in its multi-year course, is built around its appropriate and well-designed themes characterized by originality, creativity, challenges and surprises to attract the interest of the participants, as it is necessary in any such competition. As observed in evaluations of its application and analyzes of its themes, these can be satisfactorily matched with the levels of cognitive abilities of the revised Bloom's taxonomy,[57] while most of them correspond to high levels, such as understanding, applying, analyzing and evaluating. Also, although it is particularly difficult to predict the level of difficulty for each age group of participants, as mentioned in the relevant section, it seems that the topics respond satisfactorily to the cognitive level of the students, according to their age, a very important fact, as an educational competition it should be able to attract students, enhancing their interest in engagement and investigation in the field with which it deals.[30]

After all, the topics of a competition, in order to be useful and fulfill its purposes, do not necessarily have to be difficult or complex. Thus, Bebras topics provide students with problems that expose them to new knowledge or a concept that they may not know at all before.[58] In addition, the competition topics are treated very positively by teachers, who support students towards their solution, and can be used to develop teaching activities, even for students at a young age, as they have the potential to introduce many and advanced concepts in a short time, exerting a visible influence on their interest in the IT field. In this perspective, it would be very useful to focus on creating topics suitable for younger student ages and for girls in particular, which show that if they join the competition from an early age, they will later maintain their engagement with it and thus with the field of Information Technology (IT) in general. Furthermore, beyond its educational character, and although the competition is not conducted with the aim of evaluating students' knowledge, it could in the future, if utilized in an appropriate way, acquire this dimension as well.[40]

After the evolution and modification of the nature of the Bebras competition in the passing years since 2004, which now turns towards Computational Thinking, modifications are needed with defined categories that will include the ways in which CT skills can be developed and be cultivated through competition. One such proposal, more focused on Computational Thinking, alongside Informatics concepts in basic education is the two-dimensional categorization system.[34,44] Features of this proposed system will be detailed below.

There are various compete sets of activities for students' of different age range within a Bebras challenge, like the UK Bebras case study, in which six age groups are proposed: **Kits** for students between 6 to 8 years old, **Castors** for students between 8 to 10 years old, **Juniors** for students between 10 to 12 years old, **Intermediate** for students between 12 to 14 years old, **Seniors** for students between 14 to 16 years old, and **Elite** for students between 16 to 18 years old.[66]

All the above references to improvements and changes in the system of categorization of the competition's subjects, make evident the importance given to its subjects and the weight that their good quality has for the researchers and in general for all the participants in it. For Bebras and all problem-based competitions in IT and beyond, the quality of their content should be a primary concern of the organizers. The criteria for quality assurance are many and varied and quite difficult to make them very specific. In an attempt to present them in a centralized manner, reference is made to the most prevalent of the elements that should characterize the topics of the competition. These include:

1. Short sentences in question wording, which are easy to read and lead to quick understanding of their content.
2. Repetition of words or phrases, which give coherence when longer sentences break up.
3. The clarity of definitions and the non-misleading or ambiguous nature of wording, leading to a better understanding of the subject, are essential.
4. Finally, appropriate proportions and the maintenance of a one-to-one relationship between objects and words-linguistic terms, without the use of different or synonymous words, favor the quick understanding and correct interpretation of the requested subjects.[47]

The development of themes is a process that includes a variety of activities and requires various resources, while during their preparation both the creators and judges are involved, as well as administrators, programmers, teachers and finally the participating students. In the initial phase of the selection, a group of

8-10 topics is selected that are considered the most appropriate by the national representatives-creators of each participating country and forwarded to the topic repository (Repository-SVN), at least one month before the workshop. During the annual international workshop, experts from the Bebras community judge, refine, modify and finalize the format of the topics. Thus, the repository is refreshed and fed with the final themes.[34,35,44,71]

After this stage, the representatives of each country choose the most suitable for the national given topics that will be used in the competition, after they have been translated into the respective language, under the supervision of a specialist linguist. Next, the necessary preparation is done by the managers of the management systems, and the manager creates a set of approved tasks, according to the age groups of the participants.

The subjects reach the students who proceed to solve them and enter their answers in the system under the supervision of the teachers. After the end of the competition process, the topics are accessible and open for comments and discussion, and later, after being archived by the management system, they can be reused.[35,68]

Bebras, like competitions of a similar nature, playful, aimed at an audience without specialized technical knowledge, is a particularly effective way of conveying the interest and joy that being involved in the field of IT can bring.[55,60] The constant desire and will of the students to participate in the competition every year and solve its topics successfully, can be considered as a positive sample of how successful it is as a method of learning and teaching IT. Thus, gamified learning approaches seem like a promising solution to strengthen students' motivation and engagement with aim to achieve better learning outcomes. One of the main objectives of the competition is to integrate computer science into the learning process and understand the aspects of technology through the use of computer systems. For students participating in it, the goal is to broaden their understanding of what functions a computer serves in human hands, beyond entertainment, file playback, and social networking. One of the desired results is for them to come into contact with the possibilities that Computer Science and its various fields can offer them, perceiving the computer as an inexhaustible source of interesting activities-problems that can support the cultivation of various forms of thinking and skills.[56]

To achieve these goals, the competition topics are adapted according to certain criteria. The mandatory criteria, which despite the intense difficulty, must be respected in every subject of the competition, include the time limit of three minutes that can be allocated for their solution, as well as the possibility of presenting them on a single computer screen. At the same time, another mandatory criterion is the easily understandable formulation of the problem and their independent character from specific information systems. In order to meet all the above criteria at the same time, it becomes clear that Bebras topics cannot be practical IT problems, which are extensive, but focus on some at a time, smaller aspects and specific learning objects. In addition, their detachment from specific information systems shifts their focus to understanding the principles, ideas and basic concepts included in those systems. Also, the mandatory computer-only solution should also be supported by features that will lead to easier understanding, explanation and computer-based solution of the issues. These characteristics are the interactivity that the computer can offer and the fun that can arise through it.[35,38]

In the context of the competition, the term "*concepts of IT*" is used, as its short-term topics can only include certain aspects of its fundamental ideas. Nevertheless, the four criteria that the fundamental ideas meet are taken into account. These, according to Schwill,[72] are: (i) the horizontal criterion for applying ideas in various ways in different situations, (ii) the vertical criterion for learning the idea at each intellectual level, (iii) the criterion of time concerning the continuous presence of the idea that evolves historically and will continue to be observed in the long term and (iv) the criterion of logic (sense), which requires the idea to make sense in everyday life and relate to ordinary, used language.

Thus, in the Bebras competition, the topics created contain concepts and processes of computer science, which have the prospect of remaining interesting in the long term, easily understood and applicable in other areas, while being understood at different intellectual levels. In addition, with the correct formulation of the topics, almost any concept of Information and Communications (ICT) technologies can be their content.[35,38,44,71]

For the introduction and understanding of a new idea or concept of Informatics, a path is followed that could be illustrated in a spiral (see figure 7), starting from the concept itself, the learning of which is the educational goal. The interesting and fun context in which it will be included, along with the addition of gamification and interactivity, leads to the creation of a theme for the student competition. The resolution of this and many other issues related to the concept, as well as their subsequent processing and discussion, with the appropriate and necessary support of the teacher, will lead to clarification and strengthen the mastery of the concept.[4,17,67,70,73]

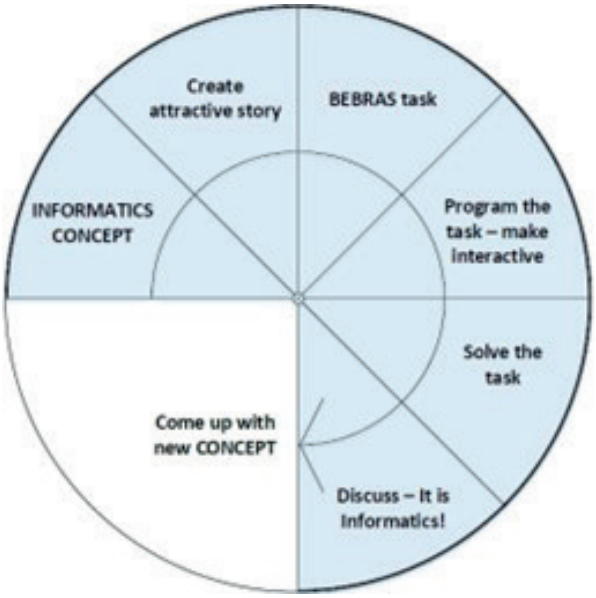

Figure 7. Spiral illustration of the course of introducing and understanding a new concept

Within this broad spectrum that Bebras topics can cover in relation to Informatics, algorithms and programs, various data representations, situation modeling, human-computer interaction, the use of graphics and many others are included. For the best possible utilization of its subjects in the education of Computer Science in the school reality, and the support of teachers towards the correct and appropriate selection of material for use in the educational process, the categories proposed by the two-dimensional system of Dagiene et al.[44], focus alongside Computational Thinking skills, on five main axes of Informatics. These in particular are:

1. Algorithms and programming, along with logical reasoning
2. Data, data formats and representations including the use of graphs, data extraction, etc.
3. Computer processes and hardware, related to anything related to computer operation, programming, etc.
4. Communication and networks
5. Interaction (HCI - human-computer interaction) and all other issues concerning systems, society, etc.

The topics of the competition can be used in the educational process, after they are categorized and a correct choice is made, depending on the teaching needs, with the aim of deepening algorithmic, functional, logical and computational thinking. The use of charts and various graphs to represent data, the sequence of logical operators (AND, OR, NOT functions) to solve problems and the use of social networks with which students are familiar from their daily work are just a few examples of variety of topics that can be present in the "warehouse" of the competition, allowing their use in the educational process throughout the year, regardless of their competitive nature, thus introducing students to both the concepts of Information Technology and the basic aspects of Computational Thinking.[40] The instruction-explanation of each activity in relation to Information Technology and Computational Thinking contained in the accompanying field "*It's Information Technology*", and the possibility of immediate access to the result, can encourage their integration into the school curriculum, empowering the teacher to include them in his teaching in an optimal way.[17]

In the two-dimensional system of categorizing the activities of Bebras, Dagiene et al.[44] mentioned above, the axes of Computational Thinking can be seen that are used alongside the concepts of Informatics, attempting to learn its basic skills by students. These knowledge and skills fall into five main categories of Computational Thinking, which are as follows:

1. Abstraction
2. Algorithmic thinking
3. Decomposition
4. Evaluation
5. Generalisation

Due to the different ways in which each student-contestant can think towards the solution of each issue, which may or may not coincide with the way originally proposed by the creator of the issue, each of them may fall under in one to three of the system's Computational Thinking categories. The Bebras competition seems

that it can be a source that will feed the learning process with additional educational tasks, since, with a correct categorization of its topics, it can give the teacher the opportunity to choose specific topics, according to the current content of his/her teaching. Such a categorization, suitable to support the teaching of Computational Thinking skills, is based on the operational definition (ISTE-CSTA) and includes the logical organization and logical analysis of data, as well as the representation of information with digital, diagrammatic, and other forms. Also, algorithmic thinking is included in the categorization, with automation of operations, and strategy identification, which refers to solving problems with non-trivial algorithmic approaches. Finally, two more categories concern the analysis of algorithmic solutions, e.g. in terms of their correctness and complexity and the application of these algorithmic solutions, in programming or coding tasks.[55,60]

However, apart from its competitive nature, it can be seen that Bebras' potential and the prospects for exploiting its potential are remarkable. Another characteristic that makes it stand out among other competitions related to computers and computer science is that its logic is based on active learning (learning-by-doing), with a fun and challenging character. Its problem-based topics support exploratory learning and familiarity with the required subject matter, allowing all, not just gifted students, to participate and succeed.[61]

Through the case study of the Bebras competition, in the context of initiatives to promote Computational Thinking (CT) at school, it appears that this is an effective way of cultivating its skills, since based on its originality and its playful and entertaining format, it supports learning, improves and it upgrades its framework, while at the same time, it strengthens the motivation and interest of the participants.

Extending the possibilities of the Bebras Challenge, beyond the dimension concerning the utilization of its subjects as teaching tools, mentioned above, a second possible dimension is attributed to it. This concerns the use of the competition as a future mechanism for evaluating the mastery of CT by students. Compared to other tests or competitions, it appeared to provide a naturalistic-authentic framework defined by everyday issues, which makes it more suitable for this use. In this direction, there are also proposals to improve certain aspects of it, in order to include more axes of CT and to facilitate the utilization of its topics through the creation of categorized thematic files, for easy search and use.[62]

The characteristics of the competition and especially those of its subjects, such as their scope, duration and method of solving them, their easy-to-understand content, make it suitable for additional uses, expanding even more the field of its utilization in the wider field of Information Technology. One such possibility is the use of its subjects as a methodological tool to assess the level of programming and algorithmic skills, before and after the implementation of teaching interventions in related research.[63]

All the above positive examples are reinforced by the opinions of the participants recorded in surveys aimed at evaluating the application of Bebras in different countries. In Sweden, it is highlighted among other initiatives to integrate Informatics and Computational Thinking into the core curriculum, the aim to involve as many schools as possible with the Bebras Challenge, since by its nature, it can activate the interest of the participants towards these sectors. In fact, over time, the competition gathers more and more entries, with the percentage of girls at the same time increasing significantly.[64] In Turkey, the first application, in 2015, found all contributors particularly positive towards the organization, as they felt that it works supportively in the teaching of Information Technology, enhancing learning through fun, with topics that required attention and logic. The students seemed motivated and eager. Of course, there were also negative evaluations, from students who found the process difficult or boring, while many wanted the results to be announced, but also for there to be some prize or gift for good performance or participation, which did not exist.[65]

Furthermore, through a parallel analysis of data from Finland, Sweden and Lithuania (competition 2013), it appears that, in most age groups of all three countries, there was a lack of easy-to-solve issues, which can be an inhibiting factor in participation of students, but also of teachers, who may feel afraid and avoid it. This reinforces the need for careful selection of topics and highlights the demanding nature of predicting their level of difficulty. At the same time, however, it also provides evidence for the investigation of possible common misconceptions of students at specific ages. These samples give rise to continuous research aimed at maintaining quality, cooperation between participating countries to smooth out differences and avoid possible additional obstacles.[43,68]

RQ2.What is the impact and effectiveness of a gamified learning approach included in Bebras initiative for promoting computational thinking skills among students?

The Bebras competition, or so called "Bebras Challenge", seems to be one of the largest IT competitions internationally. Participating students, who are divided into various age groups from the youngest of primary school to the oldest of secondary school, are asked to solve in a period of 40 to 60 minutes, 15 to 21 task-issues for which however, no specific prior knowledge is required. The problems to be solved in each topic are usually introduced in the form of a story-situation, without technical terms, and their solution requires the utilization and application of some aspect of Computational Thinking, while they include concepts from almost all fields of Computer Science.[35,44,71]

Researchers' work collectively contributes to a better understanding of how initiatives like the Bebras competition and gamified learning approaches could promote computational thinking skills and enhance problem-solving abilities among students across different educational contexts. So far, some researchers have tried to investigate the Bebras educational competition and its impact on the development of computational thinking skills. Dagiene has been actively taken part in researching computational thinking development through initiatives like the Bebras competition and contributed to various publications on this subject area.[44] Also, she has been actively involved in researching both the Bebras competition and gamified learning approaches for computational thinking development. A great part of Dagiene's research is mainly consisted of comparative studies on students' problem-solving strategies in Bebras challenges, analyzing the development of CT skills among students in different countries. Her work sheds light on the effectiveness of Bebras tasks in promoting computational thinking and problem-solving abilities.[35,44] Román-González and colleagues have done an incredible work in the field of computational thinking (CT).[51,52] Their work is aligned with the Bebras initiative. Specifically, Román-González developed a Computational Thinking Test (CTt) aimed at Spanish students between 12 and 13 years old,[53] which has been used alongside Bebras tasks to assess CT skills. Also, Zapata-Cáceres, Martin-Barroso and Román-González in their work entitled "*Collaborative Game-Based Environment and Assessment Tool for Learning Computational Thinking in Primary School: A Case Study*",[52] they developed a game-based environment designed both for learning and assessing computational thinking (CT) skills in primary school students. Next, Bell has advocated for the use of hands-on activities, games, and puzzles to teach computing concepts effectively, as evidenced in his "*Computer Science Unplugged*" series.[45,46] Bell is a full member of the International Bebras Committee (IBC). While his "*Computer Science Unplugged*" series does not directly reference the Bebras initiative, both share a common goal that is, introducing computational thinking to students through interactive and gamified methods. The methodologies of *CS Unplugged* have influenced educational tools that incorporate Bebras-like tasks. For example, a card game was developed to help high school students discover algorithms through unplugged activities inspired by Bebras tasks.[78] In addition, Bers has conducted research on the intersection of technology and education, including studies on computational thinking development in young children through utilizing tools like Scratch. She examines how such tools help in the development of computational thinking and integrate playful learning with educational goals. The Bebras challenge is an international initiative that introduces computational thinking to students through short tasks and problems. Bers' work aligns with Bebras initiative, emphasizing the importance of scaffolding computational thinking in early education.[48,74] Yadav's research interests also include computational thinking in education. A great part of his research is focused on how computational thinking can be effectively taught and fostered in K-12 classrooms, aiming to prepare students for 21st-century problem-solving. His work also explores pedagogical approaches for embedding these skills in the curriculum.[4,49,70] Furthermore, Yadav's research examines how game-based learning can enhance the development of computational thinking and student engagement. For instance, in the study "*Computational Thinking in Elementary and Secondary Teacher Education*," Yadav and his colleagues explore how game-based learning can improve teachers' computational thinking skills that are necessary in their effort to help students develop CT skills at K-12 level.[70] Additionally, Repenning et al.in the work entitled "*Scalable Game Design: A Strategy to Bring Systemic Computer Science Education to Schools through Game Design and Simulation Creation*,"[50] emphasized on how game design and simulation creation can be utilized to help K-12 students to engage in computational thinking.

Specifically, when investigating Bebras contest and gamification for the development of students' CT we should focus on the following aspects: (i) **problem-solving**: Bebras challenges are properly designed to foster problem-solving skills. These problems often present real-life learning scenarios or puzzles that require logical thinking and creative problem-solving strategies to be solved. Students need to analyze the problem, break it down into smaller components, identify patterns, and devise algorithms to come to a solution. Bebras challenges go beyond simple exercises; they simulate real-world problems that require complex problem-solving skills. These problems often lack a clear-cut solution and require participants to think critically, experiment with different approaches, and adapt their strategies based on feedback. By engaging with these challenges, students not only learn how to solve specific problems but also develop general problem-solving skills that are applicable across various domains. (ii) **logical reasoning**: Bebras tasks often require logical reasoning to identify patterns, make deductions, and draw conclusions. Strengthening logical reasoning abilities could improve academic performance in computer science, mathematics, engineering, and other subject areas. (iii) **algorithmic thinking**: students learn to think algorithmically, breaking down problems into smaller, manageable steps and devising systematic approaches to solve them. This skill is fundamental in computer science but also has applications in fields like engineering, business, and healthcare. (iv) **creativity and innovation**: While computational thinking involves structured problem-solving, it also encourages creativity and innovation. Students may come up with novel solutions or approaches to problems, fostering creativity and out-of-the-box thinking. (v) **preparation for future careers**: In a continuously developing digital world, computational thinking skills are in high demand across various industries. Participating in Bebras contests

might help students develop skills that are relevant for future careers in fields such as computer science and engineering, technology, and data science. (vi) **Gamification**: Bebras competitions encompass a gamified approach to learning, leveraging elements of game design to engage and motivate participants. The challenges are often presented as interactive games or puzzles, which can make learning more enjoyable and rewarding. Gamification techniques, such as scoring systems, levels, and achievements, seem to provide incentives for students to actively participate and improve their skills. By incorporating elements such as points, badges, leaderboards, and interactive interfaces, Bebras transforms learning into a more enjoyable and immersive experience. Gamification encourages students to set goals, track their progress, and strive for improvement, fostering a sense of achievement and empowerment. Moreover, the competitive aspect of Bebras competitions adds an extra layer of excitement, inspiring participants to challenge themselves and outperform their peers. (vii) **Various challenges**: Bebras competitions offer a wide variety of challenges catering to different age groups and skill levels. These challenges cover various topics within computational thinking, including logic, reasoning, algorithms, data structures, and others. By exposing students to a diverse range of problems, students are encouraged to explore different aspects of computational thinking and discover their strengths and interests. (viii) **Collaborative learning**: While Bebras challenges and learning tasks are typically solved individually, they also provide opportunities for collaborative learning. Students can discuss strategies, share insights, and learn from each other's approaches. Collaboration not only enhances the learning experience but also promotes teamwork and communication skills, which are valuable in both academic and professional settings. (ix) **Accessible and inclusive**: Bebras aims to be accessible and inclusive, welcoming participants from diverse backgrounds and with varying levels of prior experience. The challenges are designed to be language-neutral and require minimal prerequisite knowledge, making them suitable for students of all ages and educational backgrounds. This inclusivity ensures that every participant has the opportunity to engage with computational thinking concepts and develop their skills.

Overally, by engaging students in fun and challenging activities, Bebras contests provide inspiration for a lifelong interest in problem-solving and computational literacy. By combining interactive challenges with game-like elements, Bebras creates an engaging learning environment where students can develop critical thinking skills, problem-solving abilities, and a deeper understanding of computational concepts.

RQ 3. What are the key factors influencing teachers' development of skills and strategies to effectively integrate gamification in teaching computational thinking to students?

Focusing more on Computational Thinking, since experts in the field struggle to define its concept and dimensions with a universally accepted definition, it is to be expected that many teachers will be "*lost in an ocean of concepts and ideas*". The abundance of sometimes conflicting information likely makes it difficult for educators to deal with Computational Thinking in a practical way in their classrooms.[77] For teachers who do not specialize in IT, to be able to integrate basic concepts into their teaching, their choices and degree of involvement depends on their willingness to train and their enthusiasm for the object.

Therefore, it is worth studying both the role of teachers in the integration of Computational Thinking in education,[70] as well as the difficulties, misconceptions, attitudes, opinions, and training needs that arise in this process. In the formation of the complex identity of the students of the 21st century, teachers have a basic and decisive role and are called to function as modern educators in tune with the needs of the time. If they have the right support, students can feel that their engagement with Information Technology has substantial meaning, succeed in completing tasks, realize that they are capable of solving them, and observe the results and ramifications that these may have. This way they will have the necessary encouragement they need to stay active and continue to engage in the field.

Teachers, therefore, are faced with the challenge of substantial changes in curricula,[50] but also with bridging the gap between themselves and their students, who in the modern era are particularly familiar with digital media, which although they are not decisive for the field, they have their importance. It takes dedication, training, and effort to create a community of educators ready to convey to students the essence and true nature of Computational Thinking. Depending on how teachers view computer science and the perspectives they see from engaging with it, they can influence their decisions about both the tools they choose to use and the age at which they introduce them. At the same time, in order to be led to choose any teaching practice, strategy or tool, it should meet both their own needs and the needs they identify in their students, which may vary due to cognitive and learning background, social context and other factors. Along with the choice of each way to integrate Computational Thinking into the course, they should also consider the method by which it will be integrated or incorporated into the existing curriculum and active teaching subjects, while following the official curriculum and its teachers' goals. This creates a challenging environment for teachers and especially primary and secondary school teachers, who have limited time to teach several subjects anyway. If they manage to integrate the Computational Thinking tools of their choice into the existing curriculum, they will not only promote the cultivation of computational skills, but will simultaneously enhance the learning of the

remaining subjects and their application in the modern age.[70]

One of the key aspects of Bebras competition that has not been investigated seriously, is its gamified approach to learning with main aim to help students develop a fundamental computational thinking skillset. By presenting computational concepts in a fun and interactive way, Bebras might help students develop a deeper understanding of fundamental principles in computer science and related fields.[35,44] In primary and secondary education, trying to incorporate a gamified approach to learning with Bebras learning tasks into the existing curriculum, seems as a promising solution that will help to promote the cultivation of students' computational thinking. Specifically, Bebra's challenges vary in difficulty and cover a wide range of topics, ensuring that participants can continuously challenge themselves and improve their computational thinking skills.

Limitations of this study

In this section, the limitations of this study are described in detail. Specifically, academic databases are being updated daily with new records. Therefore, our results stemming from the same search process may slightly differentiate when someone runs the same search in different dates. However, the lack of existing publications in the field of students' development of Computational thinking via Bebras Educational Competition and Gamification is apparent in the several searches run in the 7 academic databases. A possible explanation is the existence of a research gap in literature that needs further investigation.

DISCUSSION AND CONCLUSION

Bebras challenge with the use of gamification seems to engage students in problem-solving tasks that promote logical reasoning, pattern recognition, and algorithmic thinking, which are key components of computational thinking. By presenting challenges in an interactive, game-based format, it encourages students to apply abstract concepts and systematically break down complex problems, fostering deeper understanding and skill development in computational thinking.

In the study of the current situation and the modern trend of integrating Computational Thinking in education, one of the main axes that emerged from this literature review is that of the role of the teacher. Teachers with appropriate training can play their role very effectively in promoting the development of students' computing skills. From research that studies the results of teachers' efforts to integrate Computational Thinking into their teaching subjects and practices, particularly promising evidence emerges that shows that establishing the connection of their teaching subjects with the concepts and dimensions of Computational Thinking can provide more incentives to include computing skills in them. At the same time, the determination of the positive effect that the inclusion and integration of computing skills has on the participation of their students plays a decisive role.

So far, the gamified approach of Bebras to learning has not been investigated meticulously to get a deeper understanding of how this new learning approach could help to better learning outcomes for the benefit of students. This systematic literature review tried to investigate how Bebras initiative might provide valuable insights into the impact and effectiveness of the initiative in promoting computational thinking skills among students, as well as identify gaps in the existing research and area for future investigation. A basic conclusion is that more future research is needed to shed light on this emerging research area.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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