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Integration of computational thinking in initial teacher training for primary schools: a systematic review

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Computational Thinking, a capacity based on the principles of computing, has been highlighted in the specialized literature as an essential skill for the 21st century, bringing significant benefits to the problem-solving process. In this way, norms for the integration of Computational Thinking in education have emerged in the educational curricula of several countries. For this integration to be successful, it is essential that the training given to pre-service teachers enables them to develop well-planned and structured interventions to promote the development of Computational Thinking. This article presents a systematic review of the literature that aims to investigate how the development of Computational Thinking has been integrated into teacher training. Eleven articles that corresponded to the selected research criteria were found, and the characteristics of their studies are analysed and presented in this article. The article concludes that it is necessary to invest in pre-service teacher training, highlighting the need for long-term and more comprehensive training covering not only the theoretical component but also the practical component, as well as reflection on practice.

KEYWORDS

computational thinking, pre-service teachers, primary school, higher education, systematic review

1 Introduction

Computational Thinking (CT) is increasingly valued in the specialized literature as an essential ability in problem-solving, and it is considered an essential skill for the 21st century by some authors (Angeli et al., 2016; Peracaula-Bosch et al., 2020). Although the term was first coined by Papert (1980), it was Wing's publication in 2006 that boosted the development of numerous studies and investigations on the integration of CT in teaching (Ausiku and Matthee, 2021; Knie et al., 2022; Menolli and Neto, 2022). Although there has been a significant increase in studies on this topic, uncertainty remains in defining what CT is and how it can be used in teaching (Macann and Carvalho, 2021; Peracaula-Bosch et al., 2020; Tsarava et al., 2022). Still, it is widely recognized in the scientific community that the development of CT brings significant benefits to the problem-solving process (Çoban and Korkmaz, 2021).

CT is a capacity that is based on computing processes (Wing, 2006). However, it is essential for everyone, not just for those who work with technology (Knie et al., 2022), nor is its development exclusively dependent on the specific use of technologies (El-Hamamsy et al., 2021). Although programming and robotics are often associated with the development of CT, the mere implementation of activities involving these resources does not guarantee the development of CT (Peracaula-Bosch et al., 2020). For the development of CT to occur, it is necessary to develop well-structured tasks designed for this purpose (Espadeiro, 2021; Salinas et al., 2024).

Over the last few years, countries such as Portugal (Rodrigues et al., 2022), Thailand (Pewkam and Chamrat, 2021), Ireland (Butler and Leahy, 2021), New Zealand (Macann and Carvalho, 2021) and Norway (Kravik et al., 2022; Nordby et al., 2022) have begun introducing CT into their educational curricula. In this context, it is essential to investigate how initial teacher training has prepared pre-service teachers to integrate the development of CT into their practices, thus raising the research problem of this study: How has Computational Thinking been integrated into the training curricula of future primary school teachers at various universities over the last 10 years?

The main objective of this systematic review is to investigate and present how Computational Thinking has been integrated into the training curricula of future primary school teachers at different universities over the last 10 years. The following research questions guiding the study were formulated:

1 What types of training have been used to develop Computational Thinking during initial training for primary school teachers?
2 How has this training been structured?
3 How has it been monitored?

2 Methods

The preparation of this systematic review followed the principles of the PRISMA 2020 Declaration (Page et al., 2021), with the inclusion and exclusion criteria for articles presented below.

2.1 Search strategy

The process of collecting articles for the systematic review took place in the second week of July 2023, using the databases SCOPUS from Elsevier, Web of Science from Clarivate and ERIC from the Institute of Education Sciences. In the SCOPUS database, articles' titles, abstracts, or keywords were searched using the terms of the following search equation: "Computational Thinking" AND ("Teacher Training" OR "Pre-service Teach*") AND ("Primary School" OR "Elementary School"). In the Web of Science and ERIC databases, the main collection of articles was searched using the same search equation in all sections of the articles.

2.2 Eligibility criteria

The following inclusion criteria were defined: (i) articles published between January 1, 2014, and July 13, 2023; (ii) articles that focus on the development of Computational Thinking in initial primary teacher training; (iii) articles that describe a training practice developed in initial teacher training; (iv) articles involving pre-service primary teachers.

The following exclusion criteria were applied: (i) duplicate articles; (ii) articles published before January 1, 2014; (iii) articles in the review phase; (iv) review articles or conference proceedings; (v) articles that did not focus on the development of Computational Thinking in initial primary teacher training; (vi) articles that did not describe a training practice developed in initial teacher training; (vii) articles that do not involve pre-service primary teachers.

The following steps were taken during the article selection process: (1) search in the select-ed databases; (2) exclusion of duplicate articles; (3) exclusion of articles outside the intend-ed time period; (4) exclusion of articles in the review phase; (5) exclusion of review articles or conference proceedings; (6) exclusion of articles that did not focus on the development of Computational Thinking in initial primary teacher training; (7) exclusion of articles that did not describe a training practice developed in initial teacher training; (8) exclusion of articles that do not involve pre-service primary teachers; (9) reading and evaluation of the articles included in the systematic review.

With the defined search equation, initially 63 articles were obtained from the three searched databases. After removing duplicate articles and articles still in review, two researchers (the first author and an external researcher) conducted an initial analysis independently and decided to exclude 31 articles as conference proceedings and 2 as review articles. Next, the remaining 18 articles were analyzed by the two researchers, with seven articles being eliminated for not providing information on the development of CT in teacher training or on a training practice developed in the training of future teachers. Figure 1 illustrates the literature search and the selection of eligible studies.

2.3 Analysis of the quality of studies

The quality of the 11 selected articles was analyzed using The Mixed Methods Appraisal Tool (MMAT), in its 2018 version (Hong et al., 2018). This instrument assesses whether studies meet the requirements depending on the design of the study being analyzed (Qualitative, Quantitative randomized controlled trials, Quantitative nonrandomized, Quantitative descriptive and Mixed methods). If the studies meet the requirement described in each item they receive 1 point, if it is not clear they receive 0.5 points, and if they do not comply they receive 0 points. At the end of the evaluation, articles that have 0 to 2 points are considered low quality, 3 to 4 points are medium quality, and 5 to 7 points are high quality. The first and last author each evaluated the 11 selected articles using this evaluation instrument. As no discrepancies arose, it was not necessary for any further researcher to intervene. Thus, Table 1 presents the evaluation of the 11 selected studies.

2.4 Description of the articles under analysis

Table 2 presents the main characteristics of the 11 articles selected for this systematic review: author/s, year of publication, country, target population of the study, and study design. This research was focused on articles that described a training practice developed with pre-service teachers. However, studies that did not focus exclusively

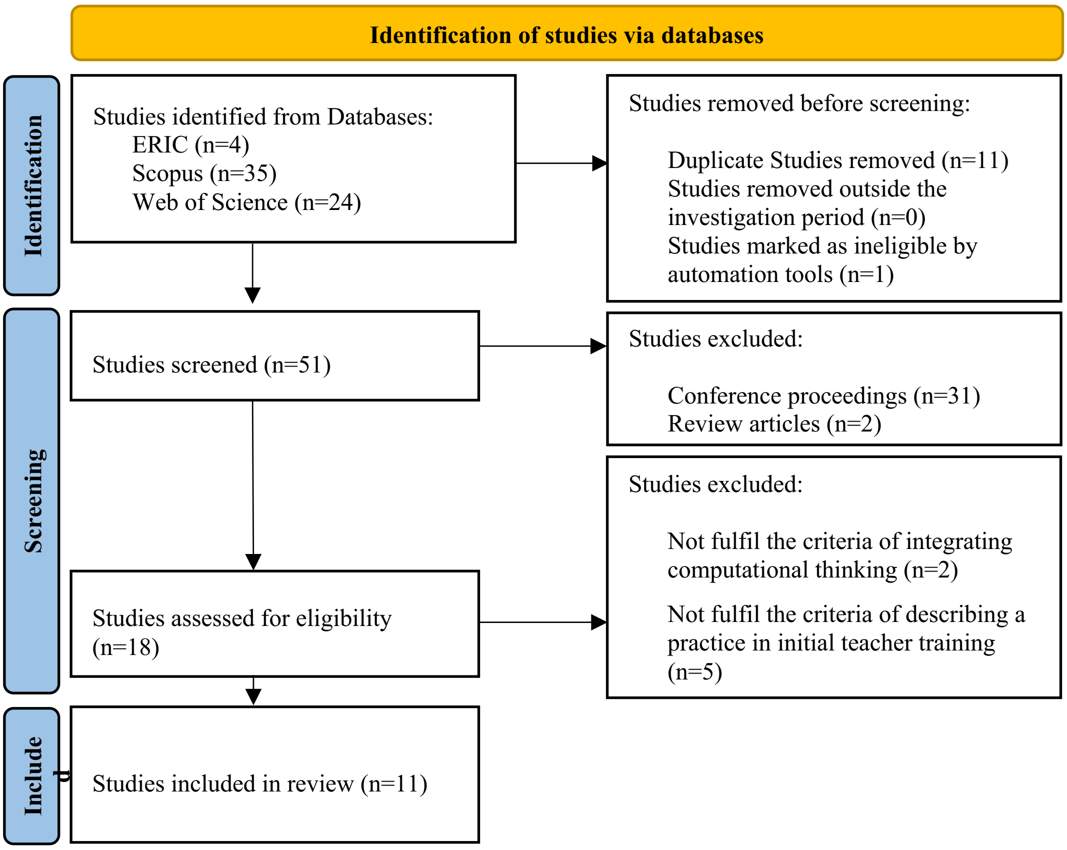

FIGURE 1
Prisma flowchart (Page et al., 2021).

on reporting practice but described a practice implemented to develop CT in pre-service teachers in any section of the article were also included. For example, articles that aimed to investigate changes in pre-service teachers' beliefs, interest, and confidence in integrating CT into their practices were included. Although a time limit of 10 years for the publication of studies had initially been defined, no article published more than 8 years ago was found in the search that was carried out.

2.5 Analyzing studies and extracting data

The procedure for analyzing the 11 studies and deciding on the data to extract was carried out by the first and last authors independently. There was only one case of divergence, which was resolved through discussion with the contribution of the second author. Thus, considering that the objective of this literature review is to investigate how CT has been integrated into training curricula at different universities, in an initial analysis the researchers decided to extract information regarding the publication year of the articles, the country where the training had been implemented, the target population of the training, and the study design (as shown in Table 1).

In a more in-depth analysis and considering the research questions, the researchers decided to identify and summarize information from the studies on the article titles, authors, intervention objectives, type of intervention, description of the training, monitoring instruments, results, conclusions, and suggestions. The summary of the included studies can be found in the Appendix.

3 Results and discussion

Of the 63 articles that were obtained through the search equation in the three databases, and after applying the already-stated exclusion criteria, 11 studies were analyzed in this literature review.

Inter-rater reliability (IRR) is crucial for the validity of systematic reviews, as it assesses the degree of agreement among researchers in the selection and analysis of studies. IRR is often measured using Cohen's kappa coefficient (Ankul et al., 2023), which quantifies the consistency between two or more raters, ensuring the objectivity and robustness of the review's results. To ensure consistency and objectivity in the initial selection of articles, Cohen's kappa coefficient was calculated (Field, 2018), which quantifies the level of agreement between two researchers (the first author and an external researcher). A Cohen's kappa coefficient of 0.90 was obtained, indicating an almost perfect agreement (Landis and Koch, 1977) between the evaluators in the study selection process. During the analysis of the 11 articles selected using The Mixed Methods Appraisal Tool (MMAT), there were no discrepancies between the two researchers (the first and the last author), resulting in a Cohen's kappa coefficient of 1, indicating perfect agreement (Landis and Koch, 1977) between the evaluators in the analysis of the studies. In the decision-making process regarding

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TABLE 1 Evaluation of articles according to the mixed methods appraisal tool (MMAT).

Studies	Screening questions		1. Qualitative					2. Quantitative rand. Controlled trials					3. Quantitative nonrandomized					4. Quantitative descriptive					5. Mixed methods					
	S1	S2	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	5.4	5.5	Score
Butler and Leahy (2021)	Y	Y	Y	Y	Y	Y	Y																					H
Drot-Delange et al. (2021)	Y	Y	Y	Y	Y	Y	Y																					H
Kaya et al. (2019)	Y	Y											Y	Y	Y	N	Y											H
Molina-Ayuso et al. (2022)	Y	Y																					Y	Y	Y	Y	Y	H
Park et al. (2015)	Y	Y											Y	Y	Y	N	Y											H
Peracaula-Bosch and Gonzalez-Martinez (2022)	Y	Y											Y	Y	Y	N	Y											H
Pewkam and Chamrat (2021)	Y	Y																					Y	Y	Y	Y	Y	H
Sáez-López et al. (2020)	Y	Y																					Y	Y	Y	Y	Y	H
Tankiz and Atman Uslu (2023)	Y	Y																					Y	Y	Y	Y	Y	H
Tripon (2022)	Y	Y											Y	Y	Y	N	Y											H
Zha et al. (2020)	Y	Y																					Y	Y	Y	Y	Y	H

Y – Yes, N – No, CT – Cannot tell. Y = 1, CT = 0.5, N = 0. Score: Low = 0–2, Medium = 3–4, High = 5–7. Items: S1. Are there clear research questions? S2. Do the collected data allow to address the research questions? 1.1. Is the qualitative approach appropriate to answer the research question? 1.2. Are the qualitative data collection methods adequate to address the research question? 1.3. Are the findings adequately derived from the data? 1.4. Is the interpretation of results sufficiently substantiated by data? 1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation? 2.1. Is randomization appropriately performed? 2.2. Are the groups comparable at baseline? 2.3. Are there complete outcome data? 2.4. Are outcome assessors blinded to the intervention provided? 2.5 Did the participants adhere to the assigned intervention? 3.1. Are the participant's representative of the target population? 3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)? 3.3. Are there complete outcome data? 3.4. Are the confounders accounted for in the design and analysis? 3.5. During the study period, is the intervention administered (or exposure occurred) as intended? 4.1. Is the sampling strategy relevant to address the research question? 4.2. Is the sample representative of the target population? 4.3. Are the measurements appropriate? 4.4. Is the risk of nonresponse bias low? 4.5. Is the statistical analysis appropriate to answer the research question? 5.1. Is there an adequate rationale for using a mixed methods design to address the research question? 5.2. Are the different components of the study effectively integrated to answer the research question? 5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted? 5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed? 5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

TABLE 2 Summary of the main characteristics of the articles.

Authors	Year	Country	Study population	Study design
Butler and Leahy (2021)	2021	Ireland	51 pre-service teachers (Degree in Primary Education) and 5 classes of children from years Four and Five (approximately 30 students per class)	Case study
Drot-Delange et al. (2021)	2021	France and Switzerland	283 pre-service teachers (master's in education)	Exploratory study
Kaya et al. (2019)	2019	United States of America	56 pre-service teachers (Degree in Primary Education)	Exploratory study
Molina-Ayuso et al. (2022)	2022	Spain	149 pre-service teachers (Degree in Mathematics Education)	Quasi-experimental study
Park et al. (2015)	2015	South Korea	34 pre-service teachers (Degree in computer science)	Experimental study
Peracaula-Bosch and Gonzalez-Martinez (2022)	2022	Spain	37 pre-service teachers (2nd year of Degree in Primary Education)	Exploratory study
Pewkam and Chamrat (2021)	2022	Thailand	30 pre-service teachers (Degree in Primary Education)	Exploratory study
Sáez-López et al. (2020)	2020	Spain	79 pre-service teachers (2nd year of Degree in Primary Education)	Exploratory study
Tankiz and Atman Uslu (2023)	2022	Turkey	37 pre-service teachers (2nd year of Degree in Educational Technology)	Quasi-experimental study
Tripon (2022)	2022	Romania	298 pre-service teachers (Degree in Primary Education)	Case study
Zha et al. (2020)	2020	United States of America	15 pre-service teachers (Degree in Primary Education)	Case study

the data to be extracted for the analysis of the 11 studies, carried out independently by the first and last authors, a Cohen's kappa coefficient of 0,86 was obtained, indicating an almost perfect agreement (Landis and Koch, 1977) between the researchers at this stage. The discrepancies observed during this process were resolved by the two authors through discussion, with contributions from the second author.

3.1 Summary of the selected studies

The objective of this systematic review is to analyze how CT has been integrated into initial primary teacher training, namely what the characteristics of the developed training are.

In order to answer the first research question "What types of training have been used to develop Computational Thinking during initial training for primary school teachers?" we can state that, in the 11 analyzed articles, training given to pre-service teachers within the scope of CT is divided into two distinct typologies: (a) modules or training actions that are inserted into already-existing curricular units in initial teacher training courses (5 studies); (b) optional courses, not integrated into the formal curriculum of initial teacher training courses (6 studies). Within the modules that were integrated into curricular units of initial teacher training, we found that two of the practices (Tankiz and Atman Uslu, 2023; Zha et al., 2020) covered the entire period of an academic semester, while the remaining three practices (Kaya et al., 2019; Molina-Ayuso et al., 2022; Sáez-López et al., 2020) consisted of sessions that took place over periods of two to five weeks during the academic semester. Regarding the optional training offered to pre-service teachers, one of the studies (Butler and Leahy, 2021) describes a specialization course that takes place over 3 years, and another study (Peracaula-Bosch and Gonzalez-Martinez, 2022) mentions an optional subject of the initial teacher training course which lasts for the entire period of an academic semester, similarly to two other optional courses (Park et al., 2015; Tripon, 2022). The remaining two studies (Drot-Delange et al., 2021; Pewkam and Chamrat, 2021) present small training actions lasting one to 3 days. The review of the analyzed studies has shown that the training provided should be incorporated into the initial teacher education as an integral part of the curriculum, rather than as a module within a course or with an optional character (Zha et al., 2020), and should be of long duration. Only through a long-term intervention approach is it possible to include a fundamental theoretical component before didactic approaches and provide the support that should be given to future teachers throughout the learning process and the development of intervention plans. By integrating the development of CT into primary school teachers' initial training and not treating it as something optional or sporadic, is it possible to promote the development of CT skills for all students from the beginning of their schooling, not just those attending schools with greater training opportunities in this area (Butler and Leahy, 2021; Salinas et al., 2024).

Regarding the second research question "How has this training been structured?" we analyzed whether both the theoretical and practical components were included, the way the practice was developed, and the type of content associated with the development of CT. All the described practices include a theoretical component in the offered training. On the other hand, only eight of the analyzed studies describe training that includes a practical component, which involves course colleagues and promotes collaborative work. Only two studies mentioned the integration of practice with primary school students in the developed training, with this practice being optional in one of them. As for the content that was covered throughout training, all studies describe practices that associate the development of CT with programming activities, four of the practices also integrate robotics throughout the training, and another three incorporate unplugged activities into the developed training. This review has demonstrated that the practical aspect is essential in the context of teacher education in CT, particularly to bridge the often-evident gaps between theory and practice (Macann and Carvalho, 2021). Future teachers must understand the definition of CT, but it is equally important for them to understand how it can be developed in educational practice. The interventions analyzed, where future teachers developed intervention plans and implemented them with their peers during training, showed that this practice creates an environment conducive to sharing learning, exchanging experiences, and reflecting on the proposals presented, promoting collaborative work (Pewkam and Chamrat, 2021). The analyzed studies demonstrate that future teachers face difficulties in lesson planning or in developing activities with students (Peracaula-Bosch et al., 2020; Tankiz and Atman Uslu, 2023), often failing to reflect on the possible challenges that students may encounter when developing CT. Thus, it becomes essential to include tasks in this area in initial teacher training programs. The results of the studies demonstrate that as future teachers design specific interventions throughout their training to implement with students, they tend to consider and reflect on the potential difficulties that students may encounter (Drot-Delange et al., 2021). Our analysis therefore highlights that future teachers should be encouraged to reflect on practice, methodological options, student learning, and their potential difficulties. Our review identifies the trend of associating the development of CT with programming activities; however, most often the training starts with unplugged activities, meaning activities that do not directly involve the use of technological devices, aligning with what is mentioned in the literature (Bjursten et al., 2023). The analyzed studies report that initially teachers express concerns and apprehensions regarding CT training, associating it with programming activities for education. However, by the end of the training, a positive change in the attitudes of future teachers is observed, supporting the conclusions of Kaya et al. (2019), which state that training can help increase motivation and self-efficacy perception of future teachers regarding this type of activity.

To answer the third research question "How has it been monitored?" we found that the most used data collection instruments in the 11 studies were pre- and post-tests. Nine of the analyzed studies chose to use pre- and post-tests to monitor the developed training, and four of these did not use any other data collection instrument other than the tests. Written productions by students, semi-structured interviews and questionnaires were mentioned as instruments used to monitor training in the same number of studies (three). Observation grids were also used in two of the analyzed studies. In our review, it became evident that, although five out of the 11 studies emphasize in their conclusions the importance of reflection in the training process (Butler and Leahy, 2021; Drot-Delange et al., 2021; Peracaula-Bosch and Gonzalez-Martinez, 2022; Tankiz and Atman Uslu, 2023; Zha et al., 2020), only one study mentioned the use of this instrument to monitor the training given to pre-service teachers. We also highlighted that several studies reflect on initial teachers' attitudes toward CT training (e.g., motivation, self-efficacy perception, confidence), however they do not present instruments that allow monitoring this aspect.

The results of the studies that were analyzed in this systematic review provide important aspects related to the development of CT in initial primary teacher training, particularly the diversity of used modalities, reflections on the possible difficulties students faced, changes in the attitude of pre-service teachers throughout training, and the positive impact of collaboration in the training process. The authors of the reviewed studies point out the lack of training offered for the development of CT as an urgent challenge that requires an immediate solution. The studies reveal that pre-service teachers often lack knowledge about CT content, resulting in low self-efficacy, interest, and confidence, reinforcing the need for training in CT. Through training, pre-service teachers acquired crucial skills for the correct implementation of educational strategies involving CT (Tripon, 2022).

4 Conclusion

This systematic review highlights the scarcity of training that promotes the development of CT in initial primary teacher training, even though more and more countries have incorporated CT into their basic education curricula in recent years.

The results underline the importance of the practical component, which is an essential part of initial teacher training, highlighting that this practice often does not occur. Practice with primary school students is essential for pre-service teachers to understand the real difficulties students face and the real impact that their plans have on learning. The prior implementation of the teaching experience planned by pre-service teachers in the initial teacher training class, with course colleagues playing the role of primary school students, enables the promotion of collaborative learning and reflection on the practice, anticipating possible difficulties.

Individual reflection is highlighted as a fundamental component in pre-service teacher training in the results of this systematic review. It was observed that training is often short and optional, which contrasts with the speciality literature that refers to the need for longer lasting and integrated training within the official initial teacher training curriculum.

4.1 Limitations and future directions

The reduced number of studies found on this topic stands out as a limitation of the present systematic review. Although the development of CT is an increasingly prevalent theme in the literature, this review shows that the search for interventions conducted in the training of future teachers still yields few results. By applying rigorous inclusion criteria such as peer-reviewed publications in indexed journals to ensure the quality of the analyzed articles gray literature was not considered, further reducing the number of initially found articles.

Following the results obtained in this systematic review, several recommendations for future research in the development of CT can be enumerated. It is recommended that future training programs involve not only a theoretical component around CT but also include a strong emphasis on the development of lesson plans or activities with students and their implementation in practice. It is also suggested that these training programs be long-term and include different data collection instruments to monitor not only what future teachers are doing but also their attitudes toward the development of CT.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RR: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing – original draft. CC: Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Writing – review & editing. FM: Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1330065/full#supplementary-material

References

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., et al. (2016). A K-6 computational thinking curriculum framework: implications for teacher knowledge. *Educ. Technol. Soc.* 19, 47–57.

Ankul, S. S., Chandran, L., Anuragh, S., Kaliappan, I., Rushendran, R., and Vellapandian, C. (2023). A systematic review of the neuropathology and memory decline induced by monosodium glutamate in the Alzheimer's disease-like animal model. *Front. Pharmacol.* 14:1283440. doi: 10.3389/fphar.2023.1283440

Ausiku, M., and Matthee, M. (2021). *Preparing primary school teachers for teaching computational thinking: a systematic review*. Learning Technologies and Systems: 19th International Conference on Web-Based Learning, ICWL 2020, and 5th International Symposium on Emerging Technologies for Education, SETE 2020, Ningbo, China, October 22–24, 2020, Proceedings, No. 12511, pp. 202–213.

Bjursten, E. L., Nilsson, T., and Gumaelius, L. (2023). Computer programming in primary schools: Swedish technology teachers' pedagogical strategies. *Int. J. Technol. Des. Educ.* 33, 1345–1368. doi: 10.1007/s10798-022-09786-7

Butler, D., and Leahy, M. (2021). Developing preservice teachers' understanding of computational thinking: a constructionist approach. *Br. J. Educ. Technol.* 52, 1060–1077. doi: 10.1111/bjet.13090

Çoban, E., and Korkmaz, Ö. (2021). An alternative approach for measuring computational thinking: performance-based platform. *Think. Skills Creat.* 42:100929. doi: 10.1016/j.tsc.2021.100929

Drot-Delange, B., Parriaux, G., and Reffay, C. (2021). Futurs enseignants de l'école primaire: connaissances des stratégies d'enseignement, curriculaires et disciplinaires pour l'enseignement de la programmation. *RDST* 23, 55–76. doi: 10.4000/RDST.3685

El-Hamamsy, L., Bruno, B., Chessel-Lazzarotto, F., Chevalier, M., Roy, D., Zufferey, J. D., et al. (2021). The symbiotic relationship between educational robotics and computer science in formal education. *Educ. Inf. Technol.* 26, 5077–5107. doi: 10.1007/s10639-021-10494-3

Espadeiro, R. G. (2021). O Pensamento Computacional no currículo de Matemática. *Educ. Mat.* 162, 5–10.

Field, A. (2018). Discovering statistics using IBM SPSS statistics. *5th* Edn. Thousand Oaks, CA: SAGE Publications Ltd.

Hong, Q. N., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., et al. (2018). The mixed methods appraisal tool (MMAT) version 2018 for information professionals and researchers. *Educ. Inf.* 34, 285–291. doi: 10.3233/EFI-180221

Kaya, E., Yesilyurt, E., Newley, A., and Deniz, H. (2019). Examining the impact of a computational thinking intervention on pre-service elementary science teachers' computational thinking teaching efficacy beliefs, interest and confidence. *J. Comput. Math. Sci. Teach.* 38, 385–392.

Knie, L., Standl, B., and Schwarzer, S. (2022). First experiences of integrating computational thinking into a blended learning in-service training program for STEM teachers. *Comput. Appl. Eng. Educ.* 30, 1423–1439. doi: 10.1002/cae.22529

Kravik, R., Berg, T. K., and Siddiq, F. (2022). Teachers' understanding of programming and computational thinking in primary education - a critical need for professional development. *Acta Didactica Norden* 16:23. doi: 10.5617/adno.9194

Landis, J. R., and Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics* 33, 159–174. doi: 10.2307/2529310

Macann, V., and Carvalho, L. (2021). Teachers use of public makerspaces to support students' development of digital technology competencies. *N. Z. J. Educ. Stud.* 56, 125–142. doi: 10.1007/s40841-020-00190-0

Menolli, A., and Neto, J. C. (2022). Computational thinking in computer science teacher training courses in Brazil: a survey and a research roadmap. *Educ. Inf. Technol.* 27, 2099–2135. doi: 10.1007/s10639-021-10667-0

Molina-Ayuso, Á., Adamuz-Povedano, N., Bracho-López, R., Torralbo-Rodríguez, M., Molina-Ayuso, A., Adamuz-Povedano, N., et al. (2022). Introduction to computational thinking with scratch for teacher training for Spanish primary school teachers in mathematics. *Educ. Sci.* 12:899. doi: 10.3390/educsci12120899

Nordby, S. K., Bjerke, A. H., and Mifsud, L. (2022). Primary mathematics teachers' understanding of computational thinking. *KI Kunstliche Intell.* 36, 35–46. doi: 10.1007/s13218-021-00750-6

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews, no. 372. Available at: https://www.bmj.com/content/372/bmj.n71

Papert, S. (1980). Mindstorms: Children, computers, and powerful ideas. New York: Basic Books.

Park, S.-Y., Song, K.-S., and Kim, S.-H. (2015). Cognitive load changes in pre-service teachers with computational thinking education. *Int. J. Softw. Eng. Appl.* 9, 169–178. doi: 10.14257/ijseia.2015.9.10.17

Peracaula-Bosch, M., Estebanell-Minguell, M., Couso, D., González-Martínez, J., and Gonzalez-Martinez, J. (2020). What do pre-service teachers know about computational thinking? *Aloma* 38, 75–86. doi: 10.51698/aloma.2020.38.1.75-86

Peracaula-Bosch, M., and Gonzalez-Martinez, J. (2022). Developing computational thinking among pre-service teachers. *QWERTY* 17, 28–44. doi: 10.30557/QW000049

Pewkam, W., and Chamrat, S. (2021). Pre-service teacher training program of STEM-based activities in computing science to develop computational thinking. *Inf. Educ.* 21, 311–329. doi: 10.15388/infedu.2022.09

Rodrigues, R., Fonseca, J., Costa, C., and Martins, F. (2022). "Artefactos Digitais, Aprendizagens e Conhecimento Didático - Contributos para Promover a Compreensão da Matemática" in Pensamento computacional: dimensões desenvolvidas numa intervenção no estágio pedagógico. eds. F. Martins, R. Pinto and C. Costa (Coimbra, IPC-ESEC), 117–134.

Sáez-López, J. M., del Olmo-Muñoz, J., González-Calero, J. A., Cózar-Gutiérrez, R., Saez-Lopez, J. M., del Olmo-Munoz, J., et al. (2020). Exploring the effect of training in visual block programming for preservice teachers. *Multimodal Technol. Interact.* 4:65. doi: 10.3390/mti4030065

Salinas, C., Seckel, M. J., Breda, A., and Espinoza, C. (2024). Integrating computational thinking into mathematics class: curriculum opportunities and the use of the bee-bot. *Int. J. Educ. Methodol.* 2024, 137–149. doi: 10.12973/ijem.10.1.937

Tankiz, E., and Atman Uslu, N. (2023). Preparing pre-service teachers for computational thinking skills and its teaching: a convergent mixed-method study. *Technol. Knowl. Learn.* 28, 1515–1537. doi: 10.1007/s10758-022-09593-y

Tripon, C. (2022). Supporting future teachers to promote computational thinking skills in teaching STEM—A case study. *Sustainability (Switzerland)* 14:12663. doi: 10.3390/su141912663

Tsarava, K., Moeller, K., Román-González, M., Golle, J., Leifheit, L., Butz, M., et al. (2022). A cognitive definition of computational thinking in primary education. *Comput. Educ.* 179:104425. doi: 10.1016/j.compedu.2021.104425

Wing, J. M. (2006). Computational thinking. *Commun. ACM* 49, 33–35. doi: 10.1145/1118178.1118215

Zha, S., Jin, Y., Moore, P., and Gaston, J. (2020). Hopscotch into coding: introducing pre-service teachers computational thinking. *Tech Trends* 64, 17–28. doi: 10.1007/s11528-019-00423-0