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Perceived Self-Efficacy and Knowledge-Test Performance in Computational Thinking Teacher Education: An Exploratory Comparative Study[1]

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Abstract: Computational thinking (CT) and educational robotics are increasingly incorporated into teacher education, highlighting the need to consider perceived self-efficacy and knowledge-test performance. This exploratory comparative study examined these dimensions across two teacher education contexts: an online program for in-service preschool teachers in Italy and a face-to-face program for pre-service teachers in Switzerland. Initial perceived self-efficacy was assessed using the Self-Efficacy for Teaching Computational Thinking (SET-CT) scale, while knowledge was assessed through a ten-item multiple-choice final test covering three domains: "Knowledge", "Use", and "Teaching". Italian participants reported descriptively higher initial self-efficacy across all domains. In the final assessment, Italian participants showed higher "Knowledge" scores, whereas Swiss participants scored higher in "Use" and "Teaching". A significant between-group difference emerged in "Use", favoring the Swiss cohort; however, a sensitivity analysis showed that this finding was largely driven by a single item concerning the robot Ozobot. As the two measures were analyzed separately and individual-level linkage was limited, the study does not establish an empirical relationship between perceived self-efficacy and knowledge-test performance. Their potential complementarity therefore remains a theoretical consideration rather than an empirically demonstrated finding.

Keywords: Computational Thinking; Educational Robotics; Teacher Education; Self-Efficacy; Knowledge Assessment.

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1. Introduction

Computational thinking refers to the set of cognitive processes that enable problem-solving by drawing on concepts inherent to computer science (Wing, 2006). Adopting this perspective in an educational context allows programming to be viewed as an opportunity to develop skills in problem decomposition, abstraction, algorithmic thinking and solution design, while avoiding the mistake of reducing computational thinking to the mere use of digital tools. The importance of this distinction in teacher training becomes evident when considering that educators are tasked with understanding these processes and translating them into learning experiences that align with the curriculum and the students' characteristics (Yadav et al., 2017). In early childhood education, key computational thinking concepts can be introduced through play and exploration, encouraging children to organize sequences of actions, make predictions, and test proposed solutions (Bers et al., 2014; Bers, 2021). The curricular relevance of these skills is reflected in the Italian STEM guidelines (Ministero dell'Istruzione e del Merito, 2023) and the compulsory school curriculum of the Canton of Ticino (Repubblica e Cantone Ticino, 2022). Technologies such as visual programming environments and programmable robots can serve as useful tools to facilitate access to these processes, although selecting them requires careful consideration of the target audience and learning objectives. Given the complexity of these tools, the time required to master them, and their potential educational applications, it is essential to train teachers in their use within educational settings (Ching & Hsu, 2024). Through exploration, teachers should be able to link the use of technology to the design of meaningful activities. In the context of educational robotics, this entails defining learning objectives and outcomes, selecting appropriate tools, and organizing experiences that can be adapted to the school environment (Negrini et al., 2025). A training framework that clarifies these connections can facilitate the transition from understanding the potential of robots to developing coherent educational pathways (Camilleri, 2017). Furthermore, the design of educational activities must take into account the conditions under which they are implemented: technical difficulties, limited availability of materials, and teachers' lack of familiarity with the tools can hinder the integration of robotics into daily practice.

Consequently, it is essential to complement design support with opportunities to address emerging issues and ensure that the training received remains grounded in practical, hands-on experience (Mangina et al., 2024). In this regard, it must be emphasized that for genuine professional development to occur, teachers need to be empowered to employ their own teaching methods, analyze their choices, and critically reflect on them in light of newly acquired knowledge (Grossman et al., 2009). A theoretical framework useful for designing such opportunities is provided by the concept of authentic learning, which demonstrates that educational tasks should be situated within the contexts where the knowledge will actually be applied. In this context, authenticity refers to the relevance of activities to the problems and demands of professional practice, as well as to their practical, operational dimension (Herrington et al., 2014). However, action alone is insufficient: according to the experiential learning cycle, concrete experience must be linked to reflective observation, abstract conceptualization, and active experimentation through a process in which the experience itself is interpreted and used to guide future actions (Kolb, 1984). Furthermore, engaging in such activities tests teachers' beliefs

regarding their ability to handle them, thereby invoking the concept of perceived self-efficacy, an individual's belief in their capacity to perform a task, which can influence not only the effort invested but also perseverance in the face of difficulties. In the context of computational thinking, professional development has been shown to contribute to teachers' self-efficacy, highlighting the relevance of considering this dimension when examining teacher education interventions (Rich et al., 2021). Direct mastery experiences are a primary source of such beliefs (Bandura, 1977), making opportunities for experimentation particularly significant in teacher training. Alongside perceived self-efficacy, the assessment of knowledge provides a further perspective on teachers' preparation in computational thinking and educational robotics. While self-efficacy refers to individuals' beliefs about their capacity to perform specific tasks, knowledge assessments provide information about their understanding of relevant concepts and principles. From a theoretical perspective, these dimensions can be considered complementary aspects of teacher preparation, although they represent distinct constructs and require different assessment approaches. Based on these premises, the study adopts an exploratory comparative approach involving two distinct teacher training contexts focused on computational thinking and educational robotics, with the aim of answering the following research question: What profiles of initial perceived self-efficacy and final knowledge-test performance emerge across two distinct computational thinking teacher education contexts?

2. Materials and Methods

2.1. Participants

The Italian course involved 20 participants, while the exact number of Swiss participants could not be established, as attendance was not mandatory. The baseline SET-CT questionnaire was completed by 16 Italian (80%) and 25 Swiss participants, while complete final knowledge-test data were available for 15 Italian (75%) and 19 Swiss participants. Individual linkage between the two measures was possible for 7 Italian and 8 Swiss participants. In the Italian cohort, 12 of the 15 participants who indicated their gender were women (80.0%); most participants were in the 40-59 age group (93.8%), and 9 out of 16 (56.3%) reported having received prior training in programming, computational thinking, or educational robotics. Demographic information was available for 24 Swiss participants: 23 were women (95.8%), 21 were under 30 years old (87.5%), and 3 (12.5%) reported having received previous training in the areas covered by the courses. The sample sizes analyzed varied by measure and domain due to missing responses and are reported in correspondence with the related analyses.

2.2. Training Programs

The Italian training program took place from September 3 to 22, 2025, while the Swiss program ran from February 2 to March 26, 2026. In both contexts, which integrated collaborative pedagogical design with computational thinking and educational robotics activities, the SET-CT questionnaire was administered at the start of the respective courses, and the final assessment took place at the end of the training period. Specifically, the Italian course, an 18-hour program held online in synchronous mode, covered fundamental concepts of coding (decomposition,

abstraction, sequencing) and educational robotics (the sense-plan-act cycle). It also included examples of classroom activities and simulations using the robots Bee-Bot, Blue-Bot, Ozobot, and Thymio, supported by videos and digital resources. Subsequently, participants worked in small groups to design an educational workshop for early childhood settings and presented their projects for discussion and feedback from the trainer. The Swiss course, by contrast, was a 16-hour in-person program that began with "unplugged" computational thinking activities. It progressively introduced the basics of robotics and the use of Blue-Bot, followed by rotating stations featuring ScratchJr, BYOR, Ozobot, and Thymio. Participants then worked in small groups to develop educational projects using the tools introduced during the course, finally presenting them in the concluding session and sharing them online on the platform for teachers Roteco (Negrini et al., 2021). Across both contexts, the collaborative design and presentation of educational projects reflected selected elements of authentic learning, particularly professionally relevant tasks, collaborative knowledge construction, and articulation of pedagogical choices (Herrington et al., 2010; Herrington & Oliver, 2000).

2.3. Instruments

To assess the participants' perceived self-efficacy prior to the training intervention, the Self-Efficacy for Teaching Computational Thinking (SET-CT) scale (Supplementary Material S1) was used; developed specifically for this study, it comprises 18 items divided into four thematic areas: knowledge of computational thinking, pedagogical knowledge, teaching self-efficacy, and assessment self-efficacy. Participants were asked to rate their level of agreement with each statement in the questionnaire using a five-point Likert scale, ranging from 1 ("Strongly disagree") to 5 ("Strongly agree"). The questionnaire was administered via the Qualtrics platform, and the response format utilized a slider. This choice is justified by the need to capture, in an integrated manner, teachers' perceptions regarding their knowledge of computational thinking, the pedagogical and instructional skills required to teach it, the use of technology, and the assessment of learning. The development of the instrument was based on an analysis of existing conceptualizations and measures of computational thinking (Tsai et al., 2021), the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006), and research findings on teacher self-efficacy in teaching computational thinking (Boulden et al., 2021). Items concerning knowledge of computational thinking reflect established concepts and processes (e.g., "*I can identify key components of computational thinking, such as decomposition, abstraction, algorithmic thinking, generalization, and evaluation*"); the TPACK framework provided the theoretical basis for items regarding the integration of content, pedagogical, and technological knowledge (e.g., "*I can use effective pedagogical strategies to teach computational thinking*"); while items addressing teaching self-efficacy (e.g., "*I feel confident answering students' questions about computational thinking*") were informed by the work of Boulden et al. (2021). Additional study-specific items were developed to address teachers' perceived competence in using educational technologies, managing technical difficulties, and assessing and monitoring students' computational thinking learning, thereby extending the coverage of the questionnaire beyond the dimensions addressed by the reference instruments. For the purposes of the present analyses, the 18 items were grouped into three composite measures, calculated as the mean of the corresponding items:

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"Knowledge" (items 1–4), referring to confidence in understanding computational thinking concepts and principles (e.g., *"I can define what computational thinking is"*); "Use" (items 5, 6, 7, 8, 12, and 14), referring to confidence in implementing computational thinking activities in educational practice (e.g., *"I feel prepared to use technologies to teach computational thinking"*); and "Teaching" (items 9, 10, 11, 13, 15, 16, 17, and 18), referring to confidence in supporting and assessing students' computational thinking learning (e.g., *"I know how to use appropriate tools to monitor students' progress in computational thinking"*). This analytical grouping was adopted to facilitate conceptual comparison with the macro-areas of the final assessment. It differs from the four thematic areas used in the original organization of the questionnaire and should not be interpreted as a validated factor structure. Participants' knowledge was assessed at the end of the training through a ten-item multiple-choice final knowledge test (Supplementary Material S2) administered via Google Forms. The test covered three domains: "Knowledge" (items 1, 2, and 4), assessing understanding of core computational thinking concepts (e.g., "*Which of the following processes is central to abstraction in computational thinking?*"); "Use" (items 3, 5, and 9), assessing knowledge of programming and educational robotics tools (e.g., "*How can the Thymio robot be programmed in preschool education*?"); and "Teaching" (items 6, 7, 8, and 10), assessing pedagogical knowledge related to age-appropriate activities (e.g., *"You are designing a ScratchJr activity for preschool children. Which learning objective is appropriate for the age group and the tool?"*). Scores were calculated as the proportion of correct answers. The domains were conceptually aligned with the SET-CT measures for descriptive purposes, without implying psychometric equivalence or direct assessment of practical teaching competence.

2.4. Ethical considerations

Before completing the questionnaire, participants were informed about the aims of the study and the types of data to be collected. Participation was voluntary, and participants were informed that they could withdraw at any time without consequences for their participation in the course. Informed consent was obtained before data collection.

2.5. Data Analysis

Data were analyzed using Jamovi (version 2.6). Since Qualtrics recorded a value of zero when the (non-mandatory) slider was not moved, these values (3 Italian and 12 Swiss records; 19 and 40 item responses, respectively) were treated as missing data, as they fell outside the intended scale (1–5). The resulting sample sizes were n = 12/14/14 (for "Knowledge", "Use" and "Teaching", respectively) for Italy and n = 15/12/7 for Switzerland. Sensitivity analyses including the zero values were also conducted. Complete data for the final knowledge test were available for 15 Italian and 19 Swiss participants. Given the limited ability to link data at the individual level (7 Italian and 8 Swiss participants), the measures were analyzed separately. SET-CT scores were analyzed descriptively, and internal consistency was assessed using Cronbach's alpha. Final knowledge test scores were compared using two-tailed Mann-Whitney U tests, reporting rank-biserial correlations and p-values corrected via the Holm method for four comparisons ("Knowledge", "Use", "Teaching" and Total).

3. Results

3.1. Reliability and perceived self-efficacy

Internal consistency was high across domains in both cohorts (Italy: α = .963–.970; Switzerland: α = .815–.973), although estimates for small subsamples require caution.

Descriptively, the Italian cohort reported higher initial levels of self-efficacy in all three domains; the "Knowledge" domain recorded the highest mean score in both cohorts (**Table 1**). This evidence was not subjected to inferential comparison tests between the groups.

Table 1: Initial SET-CT self-efficacy scores (M ± SD).

Domain	Italy M (SD)	n	Switzerland M (SD)	n
"Knowledge"	2.83 (1.06)	12	1.83 (.73)	15
"Use"	2.54 (1.05)	14	1.44 (.60)	12
"Teaching"	2.49 (1.13)	14	1.75 (.85)	7

As a sensitivity analysis, SET-CT descriptive statistics were also examined retaining zero values as originally exported from Qualtrics. Under this specification, mean self-efficacy scores were 2.66, 2.37, and 2.35 for "Knowledge", "Use", and "Teaching", respectively, in the Italian cohort, compared with 1.47, 1.18, and 1.17 in the Swiss cohort. Internal consistency was also very high ("Knowledge" α = .979; "Use" α = .976; "Teaching" α = .990). Although treating zero values as missing changed the point estimates, the overall descriptive pattern remained unchanged, with the Italian cohort reporting higher initial self-efficacy across all three domains.

3.2. Final knowledge test scores and between-group comparisons

Italian participants showed descriptively higher "Knowledge" scores, whereas Swiss participants scored higher in "Use", "Teaching", and the total score (**Table 2**). Mann–Whitney U tests identified a significant difference only in "Use", favoring the Swiss cohort (Holm-adjusted p = .026). This difference was largely driven by Q9 ("At an Ozobot station, the robots do not follow the commands. What is the most likely cause?"), answered correctly by 33.3% of Italians and 100% of Swiss participants. Excluding Q9, "Use" scores were similar between the Italian (M = .800, SD = .316) and Swiss cohorts (M = .842, SD = .239), with no significant difference (U = 137.0, p = .832). No significant differences emerged in the other domains or the total score.

Table 2*:* Final knowledge-test scores (M ± SD; Holm-adjusted p).

Domain	Italy M (SD)	Switzerland M (SD)	U	p (Holm)
"Use"	.911 (.153)	.789 (.228)	183.5	.285
"Teaching"	.644 (.295)	.895 (.159)	71.0	.026
"Knowledge"	.813 (.106)	.884 (.117)	96.0	.285
Total	.813 (.106)	.884 (.117)	96.0	.285

4. Discussion

In relation to the study's stated objective, the comparison between two distinct teacher training contexts offers an exploratory perspective on initial levels of perceived self-efficacy and final performance on knowledge tests, taking into account varying professional backgrounds and training structures. By examining both dimensions across in-service and initial teacher training contexts, the study provides descriptive evidence relevant to training in computational thinking and educational robotics. Italian participants reported descriptively higher levels of initial self-efficacy across all three dimensions considered ("Knowledge", "Use" and "Teaching"). These results can be interpreted in light of the participants' professional backgrounds and prior training experiences. The Italian participants were practicing preschool teachers, some of whom had already received training in programming, computational thinking, or educational robotics; in contrast, the Swiss participants were teachers in initial training, and only 12.5% of those who provided this information reported having undergone prior training on the course topics. The Italian group's descriptively higher initial self-efficacy can thus be viewed in relation to these characteristics, consistent with literature identifying mastery experiences and past performance as key factors influencing self-efficacy beliefs (Bandura, 1997; Nordin et al., 2017; Sitzmann & Yeo, 2013).

Regarding the final knowledge test, Italian participants achieved descriptively higher scores in the "Knowledge" dimension, whereas Swiss participants recorded higher scores in the "Use" and "Teaching" dimensions. The only statistically significant difference emerged in the "Use" dimension, favoring the Swiss cohort. However, this difference was largely attributable to question Q9, which concerned a possible reason for Ozobot failing to follow commands. When Q9 was excluded, scores were similar between the Italian group and the Swiss group, with no statistically significant differences. Previous studies suggest that direct participation in educational robotics activities can foster active engagement, problem-solving, perseverance, and trial-and-error experimentation (Kim et al., 2015). In the present study, Swiss participants interacted directly with Ozobot during laboratory activities, whereas Italian participants encountered it through videos and digital materials. Although the study design does not allow for determining its specific influence, this difference in exposure may help contextualize the results regarding individual items. No statistically significant differences emerged in the "Knowledge" or "Teaching" dimensions. Overall, the results highlight the importance of distinguishing

performance on specific knowledge-assessment items from the broader competencies involved in planning and conducting teaching activities, which require direct assessment through authentic educational tasks. Furthermore, although perceived self-efficacy and knowledge represent theoretically distinct yet potentially complementary dimensions of teacher training, their relationship was not empirically analyzed in the present study.

5. Limitations

The results must be interpreted with caution: the two cohorts differed in terms of age, prior education, professional status, course delivery format, and opportunities for direct interaction with technologies. As these were distinct educational settings rather than equivalent experimental groups, the observed differences cannot be attributed to the training program itself. Furthermore, the Swiss course did not mandate attendance, while the Italian course allowed for an absence rate of up to 20%; this may have introduced a selection bias among the participants who took the final assessment. Data availability varied across the domains of the SET-CT and the different assessment points, resulting in smaller and heterogeneous analytical samples. It was only possible to link SET-CT results to final knowledge assessment scores for 7 Italian and 8 Swiss participants, making it impossible to analyze the relationship between the two variables; additionally, the lack of a baseline knowledge test prevented the estimation of learning progress. Comparability was further limited by differences in course duration and the timing of assessments. It is possible that non-responses to the SET-CT did not occur at random, which may have skewed descriptive estimates, particularly within the Swiss "Teaching" domain (n = 7/25). The SET-CT, developed for this study based on existing literature (Mishra & Koehler, 2006; Boulden et al., 2021; Tsai et al., 2021), has not undergone independent psychometric validation; similarly, the context-specific final knowledge assessment lacks independent evidence of reliability and validity. High scores and low variability, especially in the "Teaching" domain, as well as the influence of a single item (Q9) on the difference observed in the "Use" domain, limit the interpretation of the data. Although both programs included collaborative instructional design activities, the resulting designs were neither collected systematically nor evaluated using a common rubric, which precluded a direct assessment of instructional design competencies. Future studies should utilize validated instruments, adopt longitudinal designs that include assessments of self-efficacy and knowledge both before and after training, employ larger and comparable samples, and use performance-based measures to evaluate instructional design competencies.

6. Conclusions

This exploratory study offers valuable insights for designing training programs, aimed at both in-service and prospective teachers, that focus on computational thinking and educational robotics. The results revealed distinct profiles between the Italian and Swiss groups, highlighting the importance of considering participants' characteristics and prior training experiences when interpreting educational assessment outcomes. In light of this, training programs could benefit from integrating the acquisition of theoretical knowledge with opportunities to use programming and robotics tools through activities involving pedagogical design,

implementation, evaluation, and reflection within authentic or realistic professional settings. Since perceived self-efficacy and knowledge represent theoretically distinct yet potentially complementary dimensions of professional preparedness, considering them together could foster a more nuanced understanding of teachers' readiness to integrate computational thinking and educational robotics into their instructional practice.

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Supplementary Material S1 — Self-Efficacy for Teaching Computational Thinking (SET-CT) Questionnaire

CT Knowledge

1. I can define what computational thinking is.
2. I can explain the fundamental principles of computational thinking.
3. I can identify key components of computational thinking, such as decomposition, abstraction, algorithmic thinking, generalization, and evaluation.
4. I can distinguish between activities that develop computational thinking and activities that do not.

Pedagogical CT Knowledge

5. I can plan activities that foster computational thinking.
6. I can adapt computational thinking activities for students with different ability levels.
7. I can integrate computational thinking into existing curricular content.
8. I can use effective pedagogical strategies to teach computational thinking.
9. I can evaluate teaching materials for computational thinking activities.
10. I can guide classroom discussions about computational thinking.

CT Teaching Self-Efficacy

11. I feel confident conducting computational thinking activities in the classroom.
12. I feel prepared to use technologies to teach computational thinking.
13. I feel capable of supporting students during computational thinking activities.
14. I feel able to manage technical problems that may arise when teaching computational thinking.
15. I feel confident answering students' questions about computational thinking.

Assessment Self-Efficacy

16. I know how to assess students' computational thinking learning.
17. I know how to collect evidence of computational thinking learning.
18. I know how to use appropriate tools to monitor students' progress in computational thinking.

Supplementary Material S2 — Final Computational Thinking Knowledge Test

Question 1

Which of the following processes is central to abstraction in computational thinking?

A. Finding technical solutions to mechanical problems

B. Ignoring irrelevant details to focus on the structure of the problem

C. Identifying patterns (e.g., recurring shapes in a puzzle)

Question 2

During an unplugged activity, children must program a path on a grid using directional arrows. Which concept are they primarily practising?

A. Decomposition

B. Automation

C. Sequencing

Question 3

How can the Thymio robot be programmed in preschool education?

A. A Java-based text programming language

B. Visual blocks through VPL (Visual Programming Language)

C. AI voice interfaces

Question 4

What is the purpose of repeating a sequence of commands (like a loop function) in an activity with Blue-Bot?

A. To make the robot move backwards

B. To repeat a sequence of movements without rewriting the commands each time

C. To check whether the robot has been programmed correctly

Question 5

Which of the following statements correctly describes a "plugged" activity?

A. A workshop in which a robot is built from recycled materials

B. An activity that requires digital or electronic support

C. A movement game involving logical rules

Question 6

You have a group of five-year-old children. You want them to work on spatial representation through unplugged coding. Which of the following activities is most effective for developing this competence?

A. Ask children to move freely in space while listening to music, then draw the path they took
B. Ask children to build a maze with LEGO and guide a blindfolded classmate through it using verbal commands
C. Create a grid on the floor and ask children to move a classmate or a toy according to sequences of symbolic instructions (e.g., arrows)

Question 7

You are designing a ScratchJr activity for preschool children. Which learning objective is appropriate for the age group and the tool?

A. Creating an animated story using simple visual commands
B. Building conditional structures and nested loops
C. Learning the difference between variables and logical operators

Question 8

Which of the following activities is an example of unplugged coding aimed at developing algorithmic thinking in preschool children?

A. Reciting a nursery rhyme in a circle to support collective memorisation
B. Arranging pictures in sequence to describe the steps of an everyday activity (e.g., washing hands)
C. Using blocks to build a tower freely without instructions

Question 9

At an Ozobot station, the robots do not follow the commands. What is the most likely cause?

A. The children used pastel colours that were too light
B. The colour codes were not drawn correctly or were too thick
C. The robot was not recharged after its previous use

Question 10

When designing an effective educational robotics activity for preschool, it is important to:

A. Know text-based programming languages
B. Place the activity within a narrative context familiar to the children
C. Use highly complex tools to stimulate attention