# Early Childhood Computational Thinking through Tangible Floor-Robot Programming in an eTwinning Community of Practice

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**Abstract:** This study explores how early-years teachers evaluate and implement Computational Thinking (CT) through tangible floor-robot activities within an eTwinning Community of Practice (CoP), with attention to gender-related participation patterns**.** Although CT is increasingly recognised as an essential dimension of Early Childhood Education (ECE - referring to ages 4-6 according to the Greek Education System), there is still limited empirical evidence on how teachers transform CT concepts into developmentally appropriate practice and how gender may shape children's engagement in such activities. Addressing these gaps, the study focuses on teachers' evaluations and classroom implementation of CT, their experiences with tangible programming tasks, and their perceptions of gender-related patterns in participation, support needs, and CT performance. The research was conducted over a 24-week asynchronous professional-learning programme hosted on Moodle and involved one national cohort of Greek early-years educators (N = 473). During the professional-learning programme, participants engaged in weekly STEAM-oriented CT activities and collaboratively designed classroom learning scenarios using floor robots (e.g., Bee-Bot). Survey instruments captured teachers' perceptions of CT, educational robotics, STEAM pedagogy, and gender-related classroom observations, while focus-group discussions provided complementary insights into classroom enactment. Following a DBR-informed exploratory mixed-methods approach, the research combined iterative engagement in the CoP with descriptive analysis of survey and focus-group data to identify patterns in teachers' experiences and reported classroom practices. Findings indicate consistently high levels of participation for both girls and boys, with only small gender differences. Boys appeared slightly more often in the highest engagement band but were also more likely to require ongoing support, whereas girls were more frequently described as working independently and showed a modest descriptive advantage in problem solving, sequencing, and simple algorithm design. In addition, the learning scenarios were rated as useful or very useful for cultivating CT and for fostering collaboration, communication, and problem solving in early-years classrooms. Qualitative findings identified three design features as particularly effective in supporting children's engagement: explicit sequencing supports, structured testing and debugging cycles, and the use of cooperative roles. Taken together, these findings underpin a set of practical learning-design principles for implementing CT through floor-robot activities in early childhood. More broadly, the research illustrates how an online CoP can support the adaptation of CT-focused designs into everyday classroom practice. It also contributes to e-learning research by illustrating how developmentally appropriate robotics activities within a Community of Practice may support equitable opportunities for young children to engage with foundational CT practices from the earliest years of schooling.

**Keywords**: Computational thinking, Early childhood, Educational robotics, Floor-robot programming, Tangible programming, eTwinning, Communities of practice

## 1. Introduction

Computational Thinking (CT) comprises analytical and algorithmic ways of thinking used to formulate, analyze, and solve problems (Aho, 2012). Since the mid-2000s, CT has gained prominence as a key twenty-first-century literacy, emphasized by international bodies such as the OECD and UNESCO (Bocconi et al., 2016; Organization for Economic Cooperation and Development, 2018; Scott, 2015). Policy frameworks position CT among essential science and engineering practices (National Research Council [NRC], 2012) and recommend systematic integration across compulsory education so that all children can participate fully in a digital society (Bocconi et al., 2016).

Parallel research strands connect CT with STEAM—often discussed as computational pedagogy (Yaşar et al., 2016). Beyond computer science, CT is treated as a transferable constellation of knowledge, skills, and dispositions that support designing solutions, creating systems, and interpreting human behavior (Hsu, Chang and Hung, 2018; Selby & Woollard, 2013; Wing, 2011). Cultivating CT from the early years is therefore a pedagogical and societal priority (Battelle for Kids, 2015; European Communities, 2007; Schola Europaea, 2018). Despite this momentum, integrating CT in ECE (4-6 y.o.) settings remains challenging and under-researched. This study addresses this gap by analyzing ECE teachers' attitudes and perceptions within an eTwinning Community of Practice (CoP) during a 24-week asynchronous training program. The study reports on teachers' perspectives on CT teaching via tangible floor-roaming robotic devices. This article forms part of a broader research



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programme and focuses specifically on the gender-related dimensions of children's participation and CT performance as reported by ECE educators. The objective of this study is to examine how ECE educators evaluate and implement CT-oriented floor-roaming robotics activities within an eTwinning Community of Practice and to explore teacher-reported gender-related differences in children's participation and CT performance.

## 2. Literature Review

Early conceptualizations of CT frame it as the set of thought processes used to formulate problems and express solutions executable by humans or machines (Wing, 2006). Subsequent work casts CT as reasoning about information processes and algorithms (Denning, 2011) and, more broadly, as a lens on how people think about computation (Guzdial, 2008). Definitions remain plural (CSTA & ISTE, 2011), with recent reviews identifying many variants (Foti & Bratitsis, 2025; Foti, 2025). Despite this plurality, the literature converges on three complementary views: (a) CT as a way of thinking for developing solutions executable by computers or robots (Corradini, Lodi and Nardelli, 2017b; Eickelmann et al., 2019); (b) CT as a problem-solving process (Grover & Pea, 2018; Hazzan, Ragonis and Lapidot, 2020; Zhang & Nouri, 2019); and (c) CT as a transferable thinking skill applicable to real-world problems across disciplines via algorithmic methods (Israel-Fishelson et al., 2021; Román-González et al., 2019; Shute, Sun and Asbell-Clarke, 2017).

Across definitions, a recurring **Core of attributes** includes abstraction, decomposition, algorithmic thinking, automation, and generalization supported by practices such as creating computational artifacts, testing/debugging, collaboration, creativity, and working with open-ended problems (Curzon et al., 2019; Grover & Pea, 2018; Selby & Woollard, 2014). In early-years' contexts—such as those fostered within the teachers' eTwinning CoP of this study these ideas are operationalized through developmentally appropriate, play-based designs; in this study, the focus is on tangible (on-robot) programming with floor robots embedded in STEAM-oriented activities. These core CT attributes and representative definitions are summarized in Table 1.

**Table 1: Core CT concepts and representative definitions from the literature**

| CT Attribute | Description and corresponding literature |
|---|---|
| Problem Abstraction | The process of making a problem more understandable by reducing unnecessary details and focusing on essential aspects, leading to simpler solutions (Barr & Stephenson, 2011; Lee et al., 2011; Grover & Pea, 2013; Selby & Woollard, 2013; Angeli et al., 2016; Cansu & Cansu, 2019; Huang & Looi, 2020). |
| Algorithmic Thinking | Thought processes for creating, expressing, executing, and evaluating step-by-step procedures to solve a problem (Barr & Stephenson, 2011; Lee et al., 2011; Grover & Pea, 2013; Selby & Woollard, 2013; Shute, Sun and Asbell-Clarke, 2017; Komm et al., 2020; Oyelere, Agbo and Oyelere, 2023). |
| Automation | Labor-saving execution of repetitive tasks by instructing a computer/robot to perform them quickly and efficiently (Wing, 2008; Barr & Stephenson, 2011; Lee et al., 2011; Bocconi et al., 2016). |
| Problem Decomposition | Breaking down a complex problem/system into smaller, manageable parts to aid understanding and solution design (Wing, 2006; Barr & Stephenson, 2011; Grover & Pea, 2013; Selby & Woollard, 2013; Angeli et al., 2016; Bocconi et al., 2016; Fried et al., 2018; Curzon et al., 2019; Upadhyaya, McGill and Decker, 2020). |
| Debugging | Systematic testing, tracing, and logical reasoning to predict, verify, and improve outcomes (Grover & Pea, 2013; Csizmadia et al., 2015; Angeli et al., 2016). |
| Generalization | Identifying patterns, similarities, and connections, and transferring solutions across related problems/contexts (Selby & Woollard, 2013; Csizmadia et al., 2015; Angeli et al., 2016; Grover & Pea, 2018; Zhang & Nouri, 2019; Hazzan, Ragonis and Lapidot, 2020). |

In ECE classrooms, tangible (on-robot) programming with floor roamers offers a developmentally appropriate pathway into CT: children do not merely talk about algorithms; they enact them with their and materials. In this study, such learning designs are embedded within an eTwinning CoP and examined with attention to gender-related participation patterns. Brennan and Resnick's (2012) framework of concepts, practices, and perspectives—applied with preschoolers by Dietz et al. (2019)—helps explain how CT grows through iterative task refinement informed by evidence and experience. Within this view, testing, debugging, and feedback are not add-ons but core practices through which children appropriate CT attributes via problem solving. Complementary strands in the literature emphasize developmentally appropriate ICT integration (Bers & Flannery, 2014) and the role of play and social interaction in CT development (Grover & Pea, 2013). From a cognitive standpoint, the information-processing tradition models thinking as the reception, transformation, storage, and retrieval of information (Eysenck & Keane, 2015), a perspective that aligns well with classroom work on sequencing, monitoring actions, and revising plans. Recent systematic reviews of preschool robotics interventions similarly emphasize the importance of age-appropriate, embodied, and play-based approaches for fostering CT in early childhood settings (Bers, González-González and Armas-Torres, 2021).

A growing body of research suggests that technology-enhanced learning environments can foster CT (Manches & Plowman, 2017; González & Armas, 2019), with educational robotics highlighted as a particularly effective approach for young learners (Bers, 2019). Teachers typically employ playful and experiential strategies, emphasising collaboration, learning from errors, and the introduction of foundational CT attributes through floor roamers (e.g., Bee-Bot) or block-based platforms (Lin et al., 2020; Foti, 2023). As children program virtual or physical artefacts to perform sequences of actions, they move from passive technology use to active creation; dialogue with teachers and peers scaffolds understanding (Baker & Clark, 2010; Blatchford et al., 2003).

Gender has been another focal dimension in CT research, though findings remain mixed. Several studies attribute potential gender differences to attitudes toward technology and related self-beliefs (Stein & Nickerson, 2004), while others report associations among gender, CT proficiency, and programming self-efficacy (Lee et al., 2014; Sarıtepeci & Durak, 2017). Results vary across contexts and specific CT components: some studies report minimal or no gender effects (Aşkar & Davenport, 2009; Werner et al., 2012), whereas others identify disparities that widen with age (Román-González, Pérez-González and Jiménez-Fernández, 2017). Subskill-level analyses also present variability: boys may show stronger decomposition tendencies (Tsai, Liang and Hsu, 2020), while girls sometimes outperform boys in abstraction or computational creativity (Rijke et al., 2018; Israel-Fishelson et al., 2021). Broader cognitive and socio-cultural factors intersect with these patterns, including girls' strengths in language and memory (Duckworth & Seligman, 2006) and boys' visuospatial tendencies (Gurian & Ballew, 2003). Stereotype threat, self-efficacy, and limited teacher preparation further shape outcomes (Yücel & Rızvanoğlu, 2019; Cateté et al., 2020). These findings highlight the importance of equity-oriented pedagogy, especially in early-years CT activities.

Within this context, e-learning Communities of Practice (CoPs) serve as structured environments that support teacher learning, resource exchange, and iterative refinement of CT activities. Asynchronous participation allows flexibility and accommodates diverse schedules (Nichols, 2003; Papachristos et al., 2010). In this study, an eTwinning CoP hosted on a Moodle platform facilitated collaboration among ECE teachers through discussion forums, shared artefacts, and iterative classroom enactments. The CoP followed a 24-week STE(A)M-oriented cycle that introduces tangible programming with floor robots and incorporated collaborative eTwinning project work. Deliverables—including lesson plans, grids, and photographs—are curated into shared repositories such as a collective ebook (Foti, Tzimopoulos, & Bratitsis, 2023). Table 2 presents an exemplary Social Studies learning scenario ("What will we celebrate today?") illustrating how cultural-diversity goals are integrated with CT tasks such as sequencing, testing, and debugging. This is an exemplary learning scenario for an ECE classroom, which was designed by ECE teachers while participating training activities within the eTwinning CoP. The teachers were presented with and were obliged to design their own learning scenarios for CT, utilizing floor roamers (among other materials).

Supplementary examples of classroom materials and task designs (including sequencing activities and grid-based navigation tasks) can be found in the teaching resources associated with the CoP but are not reproduced here for brevity.

**Table 2: Example Social Studies learning scenario: "What will we celebrate today?"**

| Element | Content |
|---|---|
| Subject | Social Studies |
| Subject / Study Module | Holiday traditions and cultural diversity |
| Objective | Recognition of festive and cultural symbols; discussion of meanings and traditions. |
| Summary | The scenario supports classroom discussions on holidays, traditions, and cultural diversity across seasons. Children connect holiday names to visual symbols and reflect on similarities/differences. |
| Procedure | (a) Class discussion on holidays throughout the school year in relation to seasons. (b) Present holiday cards; children identify and name them with teacher support. (c) Place holiday images on a card mat or under a transparent grid. (d) Children receive a holiday name, locate a matching image, trace the path with their bodies on paper, then program Bee-Bot to navigate the path, incorporating CT tasks (sequencing, testing, debugging). |

| Element | Content |
|---|---|
| Differentiated teaching | For advanced children, include multiple symbols and/or holidays from other countries; for children needing support, provide step cues, reduced grid size, or pair programming. |
| Collaborate | Children work together in small groups. |
| Time distribution | Multiple short iterations as needed (≈ 10–20 minutes per iteration). |
| Resources | Card mat or transparent grid/cardboard; holiday photos or images from magazines and catalogs; "Month Cards." |
| Evaluation (K–W–L–H) | Children record what they Know, what they Want to know, what they Learned, and How they will learn more (Foti & Rellia, 2023). |

## 3. Community of Practice Context and Learning Design

The study was situated within an eTwinning CoP that supported the design, implementation, and evaluation of CT activities in ECE classrooms. The learning scenarios developed within the CoP aimed to support effective teaching and learning through tangible Floor Roamer programming activities and developmentally appropriate pedagogical practices. The pedagogical stance draws on project-based, child-centered, and collaborative learning within well-organized environments (Misirli & Komis, 2014; Foti, 2022).

The learning scenarios used in the Community of Practice were informed by the TPACK framework (Mishra & Koehler, 2006), which served as a general guide for aligning computational thinking content, developmentally appropriate pedagogy, and Floor Roamer technologies. In this study, TPACK functioned as a design reference rather than as an analytical framework.

A learning scenario in this study addresses both teacher practice and classroom activity: it specifies objectives, sequences activities, outlines forms of assessment, and offers implementation guidance. As summarised in Table 2, each scenario follows a common outline that supports coherence, differentiation, and alignment with classroom expectations.

Throughout the 24-week programme, participating ECE educators engaged in a cyclical process of implementation, reflection, adaptation, and redesign. Educators implemented CT-oriented floor roamer activities in their classrooms, shared experiences and classroom evidence through Moodle discussion forums, received peer and trainer feedback, and progressively refined or developed learning scenarios. Many of the resulting classroom scenarios were subsequently compiled into a shared collection of educational resources (Foti, Tzimopoulos, & Bratitsis, 2023).

Across the CoP cycle, participating educators designed, adapted, and implemented a range of CT-oriented classroom activities using floor robots. Typical activities included grid-based navigation tasks, route planning with arrow cards, sequencing and prediction exercises, debugging tasks, collaborative role-based programming, and movement-based path tracing. Children were encouraged to predict robot movement, test programmed sequences, identify errors, and revise commands collaboratively. These activities aimed to support foundational CT concepts such as sequencing, decomposition, problem solving, and debugging through developmentally appropriate and play-based learning experiences.

## 4. Methodology

### 4.1 Research Design

The study followed a DBR-informed exploratory mixed-methods design aimed at examining teachers' evaluations and classroom implementation of CT-oriented floor-robot activities within an eTwinning Community of Practice (CoP). The work was conducted in collaboration with practitioners participating in the CoP. This design and these instruments directly addressed RQ1 (teachers' evaluations and implementation of CT-oriented floor-robot learning scenarios) and RQ2 (teacher-reported gender-related differences in children's participation, support needs, problem solving, and sequencing/algorithmic design).

### 4.2 Triangulation and Data Sources

Consistent with methodological triangulation (Robson, 2007), multiple sources and methods were combined:

- a targeted literature review on STE(A)M-oriented CT and educational robotics;
- a nationwide questionnaire administered at the completion of the CoP cycle and

- focus-group discussions with eTwinning trainers.

This blend supports convergent evidence on teachers' attitudes, perceptions, and evaluations of the CoP experience.

### 4.3 Community of Practice Context

The CoP was implemented as a 24-week asynchronous professional-learning programme hosted on Moodle. Each week, participating ECE educators were provided with CT-oriented learning scenarios, supporting materials, and implementation guidelines. Educators implemented the activities in their classrooms with children aged 4–6 years, shared reflections and classroom evidence through discussion forums, and completed weekly evaluation activities. The forum environment supported peer exchange, collaborative reflection, and feedback on classroom implementation.

Throughout the programme, educators were encouraged to adapt existing scenarios and develop new classroom activities aligned with the programme objectives. The resulting learning scenarios incorporated Floor Roamer programming activities across different curriculum areas and emphasized sequencing, route planning, prediction, testing, debugging, and collaborative problem solving. Through iterative cycles of implementation, reflection, and feedback, educators progressively refined their classroom practices and contributed learning scenarios that were later compiled into a shared collection of educational resources (Foti, Tzimopoulos, & Bratitsis, 2023).

### 4.4 Instruments and Data Collection

This study forms part of a broader research programme conducted within an CoP between January and June 2022. While the wider project involved multiple strands of data collection, this paper focuses specifically on the gender-related dimensions of teachers' evaluations of floor-robot CT activities.

The primary dataset analysed in this study derives from a nationwide electronic questionnaire administered at the completion of the 24-week CoP cycle. The questionnaire examined teachers' evaluations of innovative learning designs for cultivating computational thinking through floor-robot programming activities in ECE settings. Responses were obtained from N = 473 ECE educators.

The questionnaire included 5-point Likert-type items addressing CT, educational robotics, STEAM pedagogy, children's participation, support needs, problem-solving performance, sequencing and algorithmic design, perceived CT cultivation, and teachers' evaluations of the learning scenarios. Additional items explored broader issues related to educational robotics, STEAM pedagogy, and the integration of robotics activities within eTwinning projects. For the purposes of the study, analyses focused on items related to children's participation, support needs, problem-solving performance, sequencing and algorithmic design, perceived CT cultivation, and teachers' evaluations of the learning scenarios. Items examining gender-related classroom observations were included to explore possible differences in participation and performance between girls and boys.

To complement the survey findings, two focus-group meetings were conducted in January and April 2022 with eTwinning seminar trainers (N = 39). The discussions explored classroom implementation experiences, perceived challenges during floor-robot activities, scaffolding strategies, children's participation patterns, and the contribution of collaborative design within the CoP. The focus-group data were used to contextualize, interpret, and triangulate the survey findings.

The instruments used in the study, together with their purpose and response formats, are summarized in Table 3.

**Table 3: Overview of research instruments and response formats**

| Instrument | Purpose | Main focus areas | Response format |
|---|---|---|---|
| **Questionnaire (N = 473)** | End-of-cycle evaluation of classroom implementation | Participation, support needs, problem solving, sequencing and algorithmic design, usefulness of learning scenarios, perceived CT cultivation, gender-related classroom observations | 5-point Likert-type items and percentage-band ratings |
| **Focus groups (N = 39)** | Qualitative exploration of implementation practices | Classroom enactment, facilitation, scaffolding, debugging, cooperative roles, participation patterns | Semi-structured group discussions |

Participation- and support-related items used 5-point response scales ranging from "not at all" to "to a very high extent." Additional questionnaire items asked teachers to estimate children's observed performance using percentage bands (e.g., 0–19%, 20–39%, 40–59%, 60–79%, and 80–100%). Prior to administration, the questionnaires were reviewed by experienced eTwinning trainers to ensure clarity and relevance to ECE educational practice.

### 4.5 Timing

Data collection followed the DBR cycle: Questionnaire at end-of-cycle., focus groups mid-course (January and April 2022).

### 4.6 Participants

The second (nationwide) questionnaire was disseminated across regions to ensure broad coverage beyond the CoP's immediate locales. The highest participation rates were from Attica (21.8%) and Central Macedonia (22.5%). Regarding teaching experience, the largest subgroup reported 19–25 years (38.2%), followed by 12–18 years (31.7%). By age, most respondents were 50–59 (44.8%) and 40–49 (34.8%). In terms of education, most held a bachelor's degree (42.8%) or a master's degree (33.6%). For ICT competence, 72.3% reported Level B certification (advanced). Detailed distributions appear in Table 4.

**Table 4: Baseline characteristics of the study sample (N = 473)**

| Variable | Category | N | % |
|---|---|---|---|
| **Gender** | Female | 465 | 98.3 |
| | Male | 8 | 1.7 |
| **Job title** | Early Childhood Education and Care (ECEC) educator | 434 | 91.8 |
| | Special education teacher | 5 | 1.1 |
| | Primary school teacher | 34 | 7.2 |
| **School district** | Region of Eastern Macedonia and Thrace | 49 | 10.4 |
| | Region of Attica | 93 | 19.7 |
| | Region of North Aegean | 13 | 2.7 |
| | Region of Western Greece | 33 | 7.0 |
| | Region of Western Macedonia | 24 | 5.1 |
| | Region of Thessaly | 22 | 4.7 |
| | Region of Ionian Islands | 36 | 7.6 |
| | Region of Central Macedonia | 96 | 20.3 |
| | Region of Central Greece | 34 | 7.2 |
| | Region of Southern Aegean | 29 | 6.1 |
| | Region of Peloponnese | 21 | 4.4 |
| | Region of Crete | 23 | 4.9 |
| **Teaching experience (years)** | 1–5 | 30 | 6.3 |
| | 6–11 | 34 | 7.2 |
| | 12–18 | 150 | 31.7 |
| | 19–25 | 181 | 38.2 |
| | 26–30 | 78 | 16.5 |
| **Age (years)** | 20–29 | 12 | 2.5 |
| | 30–39 | 71 | 15.0 |
| | 40–49 | 165 | 34.9 |
| | 50–59 | 212 | 44.8 |
| | 60–65 | 13 | 2.7 |

| Variable | Category | N | % |
|---|---|---|---|
| **Highest education** | Doctoral degree | 13 | 2.7 |
| | Bachelor's degree | 198 | 41.9 |
| | Second bachelor's degree | 35 | 7.4 |
| | Master's degree | 159 | 33.6 |
| | Training courses | 69 | 14.6 |
| **ICT level** | A | 81 | 17.1 |
| | B | 127 | 26.8 |
| | B1 | 139 | 29.4 |
| | B2 | 77 | 16.3 |
| | Training courses | 49 | 10.4 |

## 5. Data Analysis

Survey data were exported to spreadsheets and analyzed in SPSS v. 28.0. Descriptive statistics were used to summarize distributions for most variables, and the significance level was set at $\alpha = .05$ (two-tailed) for statistical decision making. Where appropriate, associations were examined using Pearson/Spearman correlations and cross-tabulations with $\chi^2$ tests to explore relationships among teaching experience, educational background, ICT knowledge, and attitudes toward STEAM and CT. Missing data were <5% and handled via listwise deletion.

Qualitative data from focus-group discussions were analyzed using reflexive thematic analysis. Codes were iteratively refined, and discrepancies were resolved through discussion to enhance the trustworthiness of the analysis and support triangulation with quantitative findings.

## 6. Findings

Overview of evidence

Quantitative results from the two questionnaires were complemented by notes from study-group meetings within the e-learning eTwinning Community of Practice (CoP). The statistics reported below are descriptive and summarize teachers' observations from classroom enactments of tangible (on-robot) CT activities with floor robots (e.g., Bee-Bot).

### 6.1 Participation in CT Activities (RQ2)

Participation referred to children's observable engagement in sequencing, robot navigation, prediction, testing, and debugging activities during classroom floor-robot tasks. Teachers evaluated participation using a 5-point scale ranging from "not at all" to "to a very high extent." Combining the two highest response categories, 74.9% of boys and 71.2% of girls were rated as highly engaged. Smaller shares fell into the moderate or slight bands, and very few were observed not to participate at all (boys 5.3%, girls 1.1%). Overall, the pattern suggests broadly comparable—and generally strong—participation across genders (Figure 1).

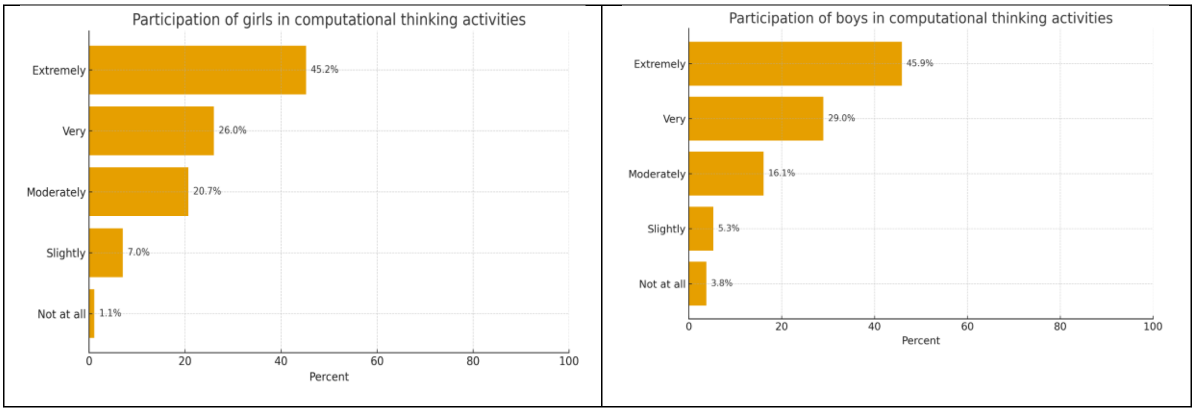


**Figure 1: Teacher ratings of girls' and boys' participation in floor-robot CT activities (N = 473)**

### 6.2 Need for Constant Support During CT Tasks (RQ2)

Support needs referred to the extent to which children required continuous teacher guidance during sequencing, navigation, testing, and debugging activities. Support included verbal prompts, modelling, step-by-step guidance, peer collaboration, and visual scaffolds. Teachers evaluated support needs using a 5-point scale ranging from "not at all" to "to a very high extent." Ratings of ongoing support needs also showed similar profiles across genders, with most children in the moderate or slight ranges. Two differences stand out:

- a larger share of girls were judged able to work without constant support (18.4% vs. 11.2% for boys),
- whereas boys were slightly more represented at the highest support level (9.1% vs. 5.9% for girls).

Taken together, these results indicate that girls were descriptively more independent in sustaining multi-step CT work, though differences were modest (Figure 2).

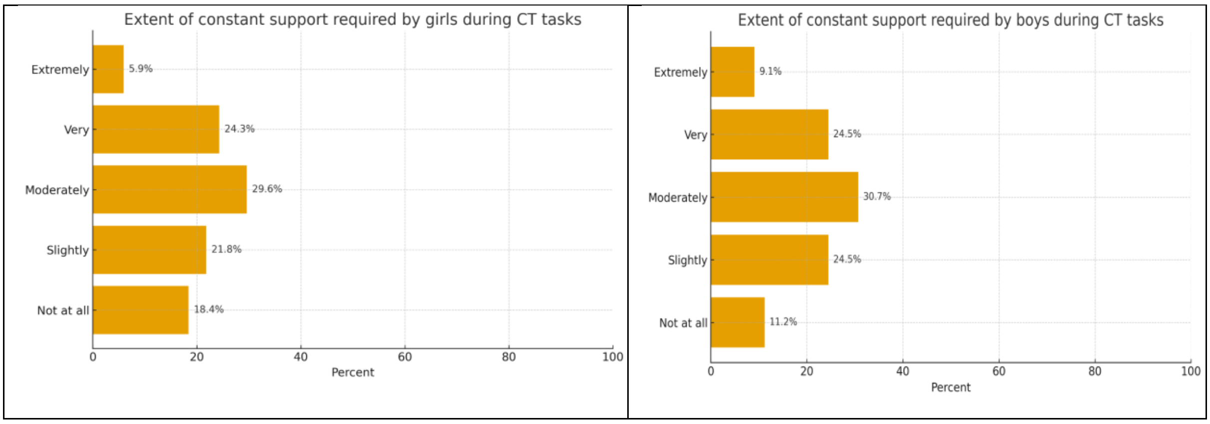


**Figure 2: Teacher ratings of girls' and boys' support needs during floor-robot CT activities (N = 473)**

### 6.3 Problem-solving Performance in CT (RQ2)

Problem-solving performance referred to children's observed ability to complete floor-robot tasks involving sequencing, prediction, testing, and correction of movement paths. Teachers estimated observed performance using percentage-band categories ranging from 0–19% to 80–100%. Distributions for computational thinking and problem-solving performance were highly similar for girls and boys. The majority in both groups clustered in the 60–79% band (boys 44.4%, girls 43.7%), with progressively fewer in lower bands. A small difference emerged at the upper end: 23.6% of girls were rated 80–100%, compared with 17.5% of boys. Descriptively, this suggests a slight edge for girls among the highest performers (Figure 3).

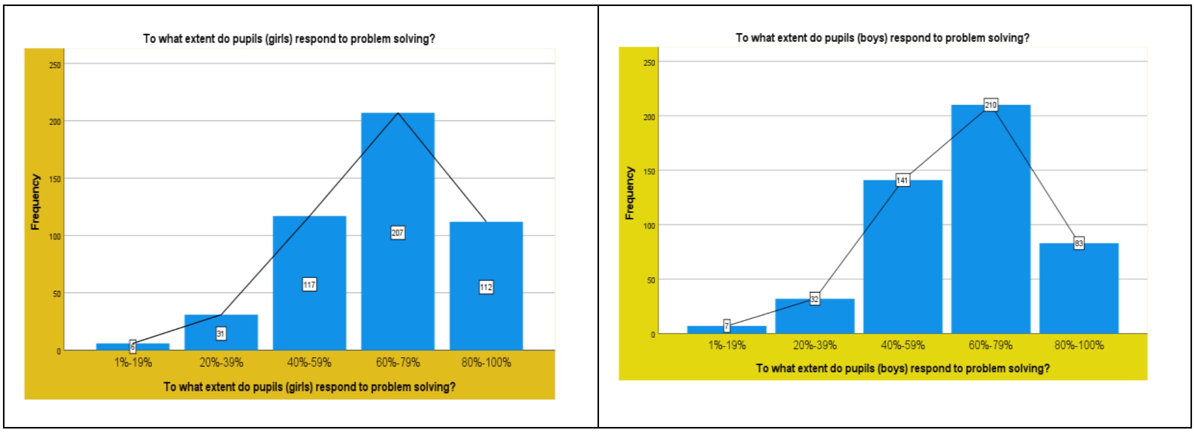


**Figure 3: Teacher ratings of girls' and boys' problem-solving performance in floor-robot CT activities (N = 473)**

### 6.4 Sequence Perception and Algorithmic Design (RQ2)

Sequence perception and algorithmic design referred to children's ability to recognize ordered steps, plan movement sequences, and revise simple command structures during floor-robot activities. Teachers evaluated these skills using percentage-band performance categories. A similar pattern appears for sequence perception and simple algorithm design. Most children again fell in the 60–79% range (boys 41.4%, girls 44.4%). At the upper end, 23.6% of girls and 19.8% of boys reached 80–100%. Overall, differences were small, with girls descriptively outperforming boys in planning, ordering steps, and refining simple algorithms (Figure 4).

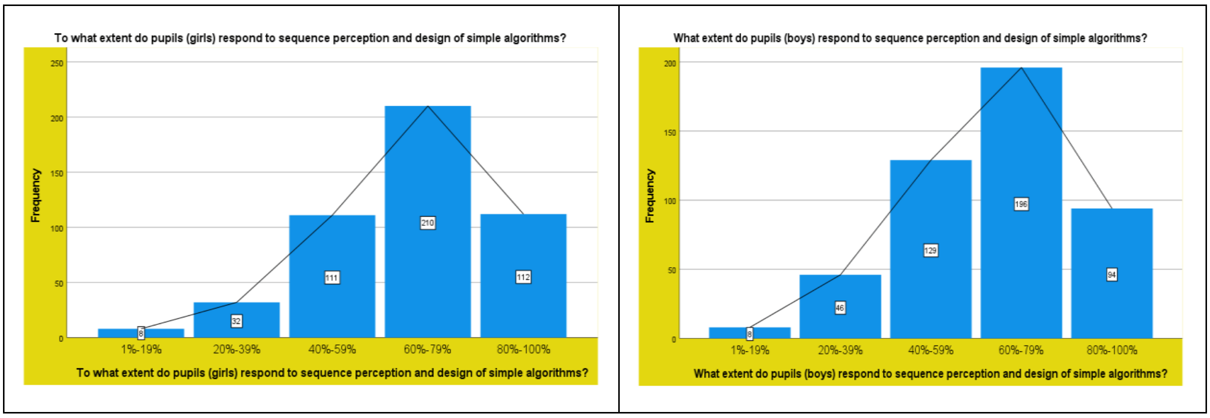


**Figure 4: Teacher ratings of girls' and boys' sequencing and algorithmic-design performance in floor-robot CT activities (N = 473)**

### 6.5 Perceived Usefulness and CT Cultivation (RQ1)

Teachers evaluated the usefulness of the learning scenarios in relation to classroom implementation, children's engagement, and perceived support for CT development. Usefulness ratings were based on 5-point Likert-type response categories ranging from "not useful at all" to "very useful." Evaluative items regarding the usefulness of the eTwinning CoP learning scenarios and their classroom impact were strongly positive. Across N = 473 teachers: 93.2% judged the scenarios quite/very useful, 96.0% reported that the floor roamer activities effectively cultivated CT skills. Only 6.8% selected "somewhat useful," and 4.0% indicated only moderate/slight cultivation. These converging ratings suggest that CoP-based designs were perceived as useful and supportive for CT development (Figures 5-6).

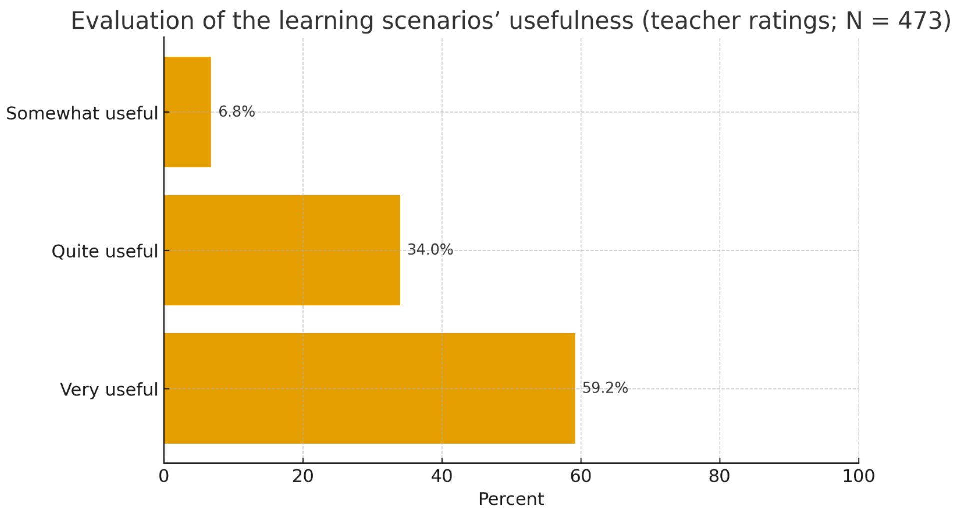


**Figure 5: Teacher evaluations of the usefulness of floor-robot CT learning scenarios (N = 473)**

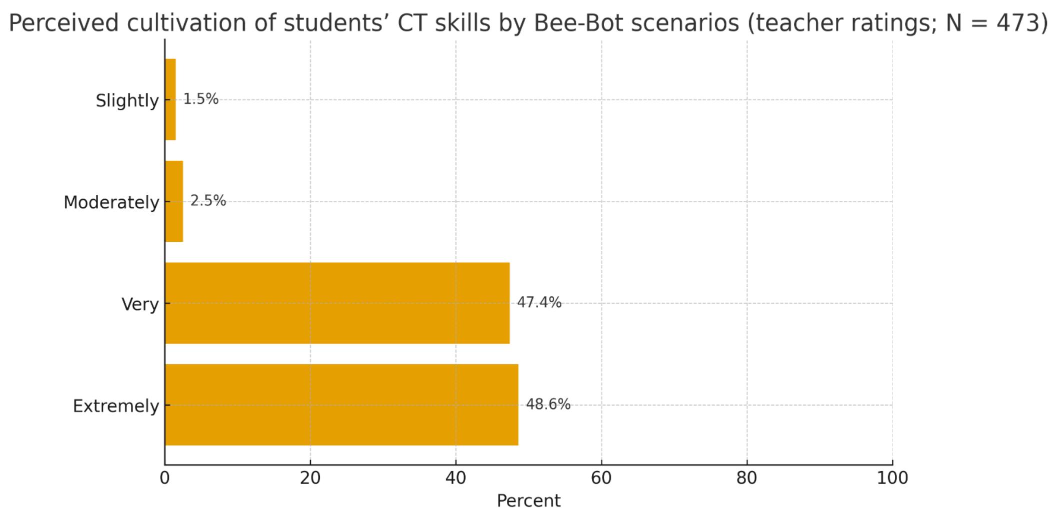


**Figure 6: Teacher perceptions of children's CT cultivation through floor-robot learning scenarios (N = 473)**

### 6.6 Qualitative Synthesis (RQ1 & RQ2)

Qualitative findings from the focus-group discussions (N = 39) complemented the questionnaire results by providing additional insights into classroom implementation practices and teacher facilitation strategies. Study-group discussions converged on three recurring design strategies that appeared to sustain engagement and reduce reliance on constant adult support: explicit sequencing scaffolds (e.g., step cards and path previews), structured testing and debugging cycles embedded within activities, and cooperative role assignment (e.g., navigator/programmer/checker).

Participants reported that sequencing supports were particularly valuable for children who initially experienced difficulty organizing movement commands and planning routes. Visual prompts and route-planning activities appeared to reduce uncertainty and facilitate participation during Floor Roamer tasks.

Participants also emphasized the importance of testing and debugging activities. Opportunities to test commands, identify errors, and revise routes encouraged children to reflect on their decisions and engage in problem-solving processes rather than simply seeking correct answers.

Finally, participants highlighted the value of cooperative role assignment. Structured responsibilities appeared to increase participation opportunities, promote collaboration, and reduce the likelihood that individual children would dominate the activity.

Teachers further emphasized the CT concepts most salient in practice—sequencing, decomposition, and debugging—informing the learning-design principles discussed later. Descriptively, these findings address RQ2 by showing small gender differences, with a modest advantage for girls in the upper performance bands and greater independence during CT work. They address RQ1 by indicating that CoP-designed tangible floor-robot activities were perceived as useful and effective for cultivating CT in ECE settings.

## 7. Discussion

This study investigated an e-learning eTwinning Community of Practice (CoP) in which early-years teachers co-designed and enacted classroom-ready learning scenarios to cultivate computational thinking (CT) through tangible floor-robot activities (Bee-Bot). Across classroom enactments, teachers consistently rated the scenarios as usable and educationally valuable and reported that the blend of unplugged and on-robot tasks supported core CT aims while engaging collaboration, communication, critical thinking, and creativity in routine practice. These findings reinforce existing evidence that developmentally appropriate robotics activities, when embedded in structured learning designs, can meaningfully support CT in early childhood settings.

The results also align with prior research on CoP-based professional learning, indicating that iterative plan–teach–reflect cycles and shared design templates (e.g., sequencing, debugging, and cooperative roles) enable teachers to translate pedagogical intentions into classroom action. Within this CoP, teachers appeared to leverage these design elements in ways that increased task clarity and reduced cognitive load for young children, which may explain the high engagement levels reported across gender groups. Similar findings regarding the importance of structured professional learning for supporting early-years teachers' implementation of robotics and CT activities have also been reported in recent teacher-development research (Yang, 2025). These observations are also consistent with research emphasizing the importance of teacher perspectives and pedagogical support structures in educational robotics implementation (Chevalier et al., 2021).

Descriptively, gender differences were small across outcomes derived from teacher ratings. Girls and boys exhibited high participation overall; boys appeared somewhat more represented at the highest engagement band yet simultaneously more likely to require ongoing support, whereas girls were more often described as working independently and showed a modest advantage in the upper performance bands for problem solving and for sequence/algorithm design. These results cohere with previous reports of slight female advantages in specific CT dimensions in early primary years and with evidence that sustained engagement functions as a lever for opportunity to learn in CT-rich tasks. While not inferential, these descriptive trends suggest that gender differences, where present, may be context-sensitive and shaped by scaffolding, task structure, and opportunities for supported autonomy.

Perceived usefulness of the learning scenarios and perceived cultivation of CT moved together in the expected direction—most teachers rated both highly—suggesting a clear descriptive association between classroom readiness of designs and their perceived impact on CT within the CoP. In practical terms, classroom-tested scenarios that include explicit sequencing supports, structured testing/debugging cycles, and cooperative role assignment appear to broaden participation while reducing reliance on constant adult guidance. This echoes the broader literature showing that well-scaffolded, embodied, and collaborative CT activities can mitigate barriers to participation, including gender-linked differences in confidence or perceived competence.

### 7.1 Limitations and Implications

The evidence synthesized here is teacher-reported and descriptive; participants were volunteers in a national CoP and may therefore represent a more motivated or pedagogically progressive subset. No direct child assessments or inferential statistics are presented, and the reliance on self-report may introduce expectancy or confirmation biases. Future work should triangulate teacher ratings with learner performance measures, analyze classroom interactions in situ, examine persistence of learning over time, and experimentally compare alternative design variants (e.g., different scaffolding intensities or cooperation structures).

Even so, the present results provide actionable direction for early-years practice and professional learning. First, embedding CT development within e-learning CoPs appears to support teacher implementation fidelity and collective capacity-building. Second, retaining explicit sequencing and debugging scaffolds in tangible floor-robot tasks helps stabilize task demands for young children. Third, structuring cooperative roles can balance participation and encourage sustained engagement. Finally, routine monitoring of engagement and support needs by gender may serve as an important formative assessment practice for ensuring equitable CT learning opportunities.

## 8. Conclusion

This study offers evidence that an e-learning eTwinning Community of Practice (CoP) can serve as a valuable mechanism for supporting early-years teachers in designing and enacting developmentally appropriate computational thinking (CT) activities with tangible floor robots. Through iterative cycles of co-design, classroom enactment, and reflection, teachers produced learning scenarios that were consistently perceived as usable, pedagogically appropriate, and effective in cultivating foundational CT skills. The strong alignment between scenario design features—explicit sequencing supports, structured testing/debugging cycles, and cooperative roles—and teachers' positive evaluations underscores the importance of intentional scaffolding when introducing CT in early childhood settings.

Across gender, participation and performance patterns were broadly similar, with only modest differences favoring girls in independence and upper-band problem-solving outcomes. While descriptive, these results suggest that well-structured, play-based CT activities may help neutralize gender disparities often reported in later educational stages, reinforcing the value of early and equitable exposure to CT-rich learning environments.

The findings also highlight the broader contribution of e-learning CoPs to professional learning in early childhood education. By providing a sustained, collaborative, and practice-centered space, the CoP enabled teachers to refine their pedagogical reasoning, deepen their understanding of CT, and translate technological tools into meaningful classroom action. This model holds promise for scaling CT integration across diverse early-years contexts.

 

Future work should complement teacher-reported data with direct learner assessments, longitudinal analyses, and experimental comparisons of alternative design elements. Nonetheless, the present study offers a clear and actionable message: when early-years educators are supported through structured, collaborative professional learning, computational thinking can be cultivated effectively, equitably, and playfully—from the very first years of schooling.

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**Ethics Statement:** Ethical approval was not required for this study. All participants provided informed consent by proceeding after reading a statement on the study's purpose, anonymity, and voluntary nature of participation. The study followed the principles of voluntary participation, anonymity, confidentiality, and responsible data handling.

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