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PARTICIPATORY TEACHER-CHILD INTERACTION IN ADVANCING TEACHING CODING AND ROBOTICS IN PRE-PRIMARY EDUCATION

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Abstract

Teacher-child interaction (TCI) and children's participation has been propounded as a factor in enhancing children's learning in formal learning settings, especially in pre-primary education. Consequently, learning basic skills in coding and robotics at an early age is necessary for constructing a knowledge base applicable in later studies. In the current study, TCI and children's participation is seen advancing young learners' (children of six years old) technology education. The theoretical framework applied in this study is the participatory teacher-child interaction model which is based on earlier research. The model consists of three domains: emotional support, classroom organisation, and participatory instructional support. These domains are further divided into specific dimensions. The focus of the study is to recognise which domains and dimensions of TCI are recognised in teaching coding and robotics. Secondarily, the study focuses on which characteristics of participatory teacher-child interaction are implemented when teaching coding and robotics. The qualitative video data were collected from six pre-primary education groups. Participants in the data (N=84) included 10 pre-primary education teachers and 74 young learners. Data were analysed with the content analysis. The results indicate classroom management as the main domain in TCI. The results also show that within classroom organisation, the dimensions of dealing with disruption and clarity of the programme of action are emphasised the

most by teachers. As a result, putting effort into classroom organisation decreases participatory TCI in teaching coding and robotics. On the contrary, the teachers who support participatory TCI place more emphasis on emotional support and participatory instructional support, and act as more competent in teaching coding and robotics. Further research is needed to increase participatory TCI when teaching coding and robotics and to further add value to technology education.

Keywords

Teacher-child interaction; participation; coding and robotics; pre-primary education

Introduction

In earlier studies, teacher-child interaction (TCI) has been considered a key variable in influencing the classroom environment (Garbacz et al., 2014), impacting, for example, children's engagement and enthusiasm in activities, protecting behavioural disengagement (Archambault et al., 2017; Pakarinen et al., 2011), the development of children's self-regulation (Salminen et al., 2021), as well as children's wellbeing (Fawley et al., 2020) and development (Hundeide & Armstrong, 2011). TCI has been argued to be a notable factor in enhancing children's learning and development in formal learning environments (Leyva et al., 2015; Pianta & Hamre, 2009), especially in early childhood education and care (Salminen et al., 2021). Research literature divides TCI into three domains: emotional support, classroom organisation, and instructional support (Hamre et al., 2013; Leyva et al., 2015; Pianta & Hamre, 2009) These studies examined TCI with quantitative means but qualitative research (e.g., Grönman et al., 2022) is still scarce.

In this study, TCI at a young age is examined in the context of technology education, specifically coding and robotics. TCI is considered as an approach which can either enable or restrain children's agency and participation. The study uses unplugged coding activities to illustrate TCI and participation in technology education for young children. Unplugged coding is often implemented through physical activity and the use of different gadgets and objects (Otterborn et al., 2019). In pre-primary education, children's participation in these coding and robotics activities is essential to support technological literacy. The idea of participation and seeing children as active agents also shares common ground with recent research on robotics projects (e.g., Alimisis, 2018).

Children's participation can be conceptualised as an entity that includes various phenomena in different social settings, for example the formal and informal (Thomas, 2012). It can be understood as taking part in activities or in decision-making and as a process or an outcome (Thomas, 2007). In pre-primary education didactics, approaches to teaching can be divided into either free-choice play, where children acquire individual experiences, or teacher-oriented structured activities (Hedges & Cooper, 2018). In teaching that supports participation, children's agency in the form of their active role and autonomy in the process of learning are key elements (Sommer et al., 2010).

Teaching coding and robotics in pre-primary education has gained attention in research for its educational benefits, such as greater problem-solving and creative thinking skills (Alimisis, 2018; Berson et al., 2019; Brainin et al., 2021; Chaldi & Mantzanidou, 2021; Falloon, 2016) as well as for logical reasoning and social skills (Berson et al., 2019; García-Valcárcel Muñoz-Repiso & Caballero-González, 2019; Papadakis et al., 2016). Research literature also recognises benefits for computational thinking and coding skills, such as sequencing, debugging, and algorithms (Brainin et al., 2021; Chaldi & Mantzanidou, 2021; Martínez et al., 2015). Notably, only a few studies have focused on different factors and conditions that influence children's learning of coding and robotics (Di Lieto et al., 2017; Jung & Won, 2018). A recent study by Grönman et al. (2022) deals with TCI in the context of technology education in early childhood education and care. However, research on TCI and participation in the context of coding and robotics is still missing.
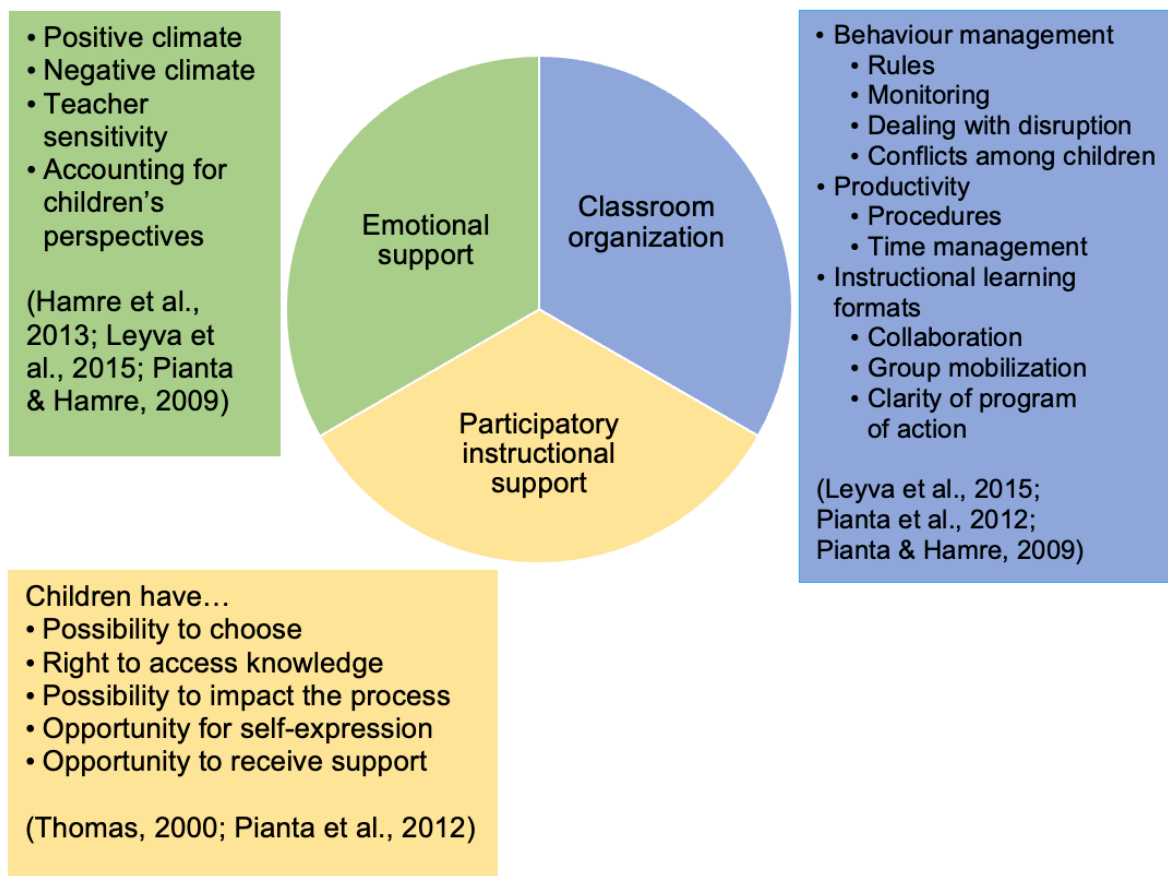
The following research questions were posed to advance the current understanding of TCI and participation in the context of coding and robotics:

1. What domains and dimensions of teacher-child interaction are recognised in teaching coding and robotics to young learners?
2. What characteristics of participation are implemented in teacher-child interaction in teaching coding and robotics to young learners?

The participatory teacher-child interaction-model

To illustrate TCI and to advance knowledge of young learners' participation as part of the open-ended learning activities, especially in coding and robotics, three theories are integrated in the theoretical framework. The framework shown in Figure 1 is based on TCI theories of the Classroom Assessment Scoring System (CLASS) measure (Leyva et al., 2015; Pianta & Hamre 2009; Pianta et al., 2012) and Teaching Through Interaction (TTI) model (Hamre et al., 2013; Pianta & Hamre, 2009). In addition, Thomas' (2000) theory of children's participation is integrated into the framework for the needs of early childhood education and care and to broaden TCI so that it covers the notion of participation. Without participation in the learning process, learners follow teachers' instructions instead of having agency in their learning.

The CLASS is a quantitative standardised observation measure of classroom qualities which can be used through all levels of education from early childhood education and care onward (Pianta & Hamre, 2009; Pianta, La Paro et al., 2008).

• Positive climate
• Negative climate
• Teacher sensitivity
• Accounting for children's perspectives

(Hamre et al., 2013; Leyva et al., 2015; Pianta & Hamre, 2009)

Emotional support

Classroom organization

Participatory instructional support

• Behaviour management
  • Rules
  • Monitoring
  • Dealing with disruption
  • Conflicts among children
• Productivity
  • Procedures
  • Time management
• Instructional learning formats
  • Collaboration
  • Group mobilization
  • Clarity of program of action

(Leyva et al., 2015; Pianta et al., 2012; Pianta & Hamre, 2009)

Children have…
• Possibility to choose
• Right to access knowledge
• Possibility to impact the process
• Opportunity for self-expression
• Opportunity to receive support

(Thomas, 2000; Pianta et al., 2012)

Figure 1. Participatory teacher-child interaction model worked after TCI and participation theories (Hamre et al., 2013; Leyva et al., 2015; Pianta et al., 2012; Pianta & Hamre, 2009; Thomas, 2000).

The CLASS is based on three domains of interaction: emotional support, classroom organisation, and instructional support. The three domains emphasise a theoretical framework called the TTI-model, which further divides the three domains to more specific dimensions (Hamre et al., 2013: Pianta & Hamre, 2009). Thomas' (2000) theory of a "ladder of participation" implements the key elements of children's participation: the choice of the children regarding their participation, information given about the situation and their rights, the control over the decision-making process, the voice they have in discussions, and the support they have been given.

Teacher-child interaction and participation in young learners' coding and robotics actions

The pre-primary classrooms are by nature social places, where TCI creates an environment in which learning occurs (Pianta et al., 2012). According to Allen et al. (2013), classrooms characterised by positivity and sensitivity to children's needs were synthesised with higher gains of children's engagement. An earlier study in young learners' technology education by Grönman et al. (2022) formed different character types of learners: talented scorers, persistent entrepreneurs, and uncertain experts; and their learning goal orientations with the prior needs for TCI. Traditionally, pre-primary classrooms are seen as places where coding and robotics are not in focus (Bers et al., 2014). Nevertheless, research has emphasised that bringing coding and robotics to young learners is possible, and preschoolers can learn to code (Bers et al., 2019; Bers et al., 2014; Elkin et al., 2014; Kyza et al., 2021; Papadakis et al. 2016).

Leyva et al. (2015) divides emotional support in classrooms into four dimensions: a positive climate, a negative climate, teacher sensitivity, and regard of students' perspectives. In this study, accounting for children's perspectives is recognised in the theoretical framework. According to Pianta and Hamre (2009), these dimensions of interaction are presumed to be critical in children's development. A positive climate comprehends the level to which children experience warm and caring relationships, respect between teachers and peers (Pianta et al., 2012; Leyva et al., 2015), and a sense of connectedness in a classroom (Pianta, Belsky et al., 2008). Expressed negativity, such as hostility and aggression, increase the negative climate in a classroom (Leyva et al., 2015). Together, the positive and negative dimensions of the climate form the overall classroom climate (Pianta & Hamre, 2009).

Teachers' sensitivity aims to respond to children's needs (Leyva et al., 2015; Allen et al., 2013). Teachers must conform and respond individually to the needs of children in the classroom (Pianta et al., 2012). Teachers with a high level of sensitivity can attend to, process, and respond to a lot of information simultaneously. Teachers' sensitivity to seize children's thinking is considered to promote children's experience of participation (Archambault et al., 2017). According to Thomas (2012), children do not perform to their full capacity if they are lacking in their sense of affection and warmth. Taking children's perspectives into consideration defines how teachers support children's sources of motivation and interests (Leyva et al., 2015). Emotional support can be considered a key element in participatory TCI.

Classroom organisation is considered to include three sub-domains: behaviour management, productivity, and instructional learning formats (Leyva et al., 2015; Pianta et al., 2012; Pianta & Hamre, 2009). All in all, behaviour management consists of how teachers set up rules and behavioural expectations and how they redirect, prevent, and monitor misbehaviour (Allen et al., 2013; Leyva et al., 2015). Monitoring undesired classroom behaviour when working with coding and robotics is important because disruptive behaviour often affects the entire classroom's activities and students' engagement (Archambault et al., 2017).

Productivity in classroom organisation is about how teachers manage different procedures and instructional time during a lesson (Pianta, La Paro et al., 2008). In pre-primary education, studies have found teachers' instructional practices to be relevant in promoting children's learning engagement and preparedness to problem-solve (Pakarinen et al., 2011). Hamre et al. (2013) divide instructional practices into general and content-specific instructions. Also, for learning skills and knowledge of coding and robotics, content-specific instructions are important (eg. Falloon, 2016; Fridberg & Redfors, 2021).

According to Pianta, La Paro et al. (2008) teacher's instructional support comprehends three aspects of teaching: concept development, the quality of feedback, and language modelling (see also Pianta & Hamre, 2009). In this study, these dimensions are connected to Thomas' (2000) theory of participation. Concept development is building connections between new and the already known information and the ability to apply and use knowledge and procedures to solve problems (Pianta et al., 2012). These aspects are parallel to Thomas' (2000) participation theory, which highlights children's right to access knowledge and receive support in their learning. Concept development also refers to the degree to which the teacher elevates higher-order thinking and focuses on understanding (Pianta, La Paro et al., 2008). This is in line with Thomas' (2000) theory of children's possibility to impact their learning by making decisions and expressing their thoughts. The quality of feedback reveals how teachers provide encouraging feedback that supports children's participation in the task at hand (Pianta, La Paro et al., 2008). Language modelling, or how teachers' model and facilitate language use in a classroom, is also a key factor in supporting learning and giving instructions (Pianta, La Paro et al., 2008).

In pre-primary education, the focus is on child-centeredness, and children are seen as active agents and allowed to take initiative while the teacher sets the frame (Sommer et al., 2010) and recognises children's autonomy (Allen et al., 2013) in TCI. The children's autonomy refers to the degree to which interaction is structured around children's interests rather than those of the teachers (Pianta et al., 2012). Autonomy is a key element of children's participation (Sommer et al., 2010). Accounting for children's perspectives is reflected in the teachers' ability to recognise and capitalise children's need for active roles and autonomy (Allen et al., 2013). In participatory TCI (Figure 1), domains of emotional and instructional support are key elements in teacher's actions. In addition, classroom organisation, especially collaboration and group mobilisation enhance learners' participation.

Method

The current study was conducted in the context of Finnish early childhood education and care with seven-year-old children, referred to in this study as young learners, participants in pre-primary education. In Finland, all young learners have a right to participate in one-year long pre-primary education at no cost before compulsory education begins at age seven. This study was conducted as a part of the InnoPlay 2018–2022 project, which was one of the key projects under the Ministry of Culture and Education in Finland aimed at enhancing technology education in early childhood education and care.

To interpret TCI, the current study used a hermeneutic approach with features of ethnographic work (Brinkmann et al., 2014; Grbich, 2007). Three university teachers carried out ethnographic fieldwork, where they provided hands-on training on coding and robotics skills to pre-primary teachers. The university teachers also participated in the unplugged coding and robotics activities and recorded video data of activities conducted with pre-primary school groups of young learners. The pre-primary teachers were novices in coding and robotics. Before the activities, the teachers participated in one to two in-service training sessions on teaching coding and robotics to young learners which lasted approximately 90 minutes. In the sessions, the teachers explored basic knowledge of coding and robotics and got hands-on training in using a KUBO robot kit. The KUBO is an educational robot which implements the principles of unplugged, hands-on coding with coding pieces called TagTiles (Figure 2).

Figure 2. The KUBO robot and TagTile coding pieces.

The data consisted of 300 minutes of recorded video data, of which 240 minutes worth of video segments were chosen for transcription and analysis. These segments were chosen according to purposive sampling, as described by Bryman (2012). There were two selection criteria for the video segments to implement interaction. The segments had to comprehend a) dialogue between the teacher and the young learners or b) teacher's instructional monologue in coding and robotics activities. Therefore, some redundant videos not comprehending TCI were left outside of the analysis. For example, videos where an individual young learner examined the KUBO robot or just played with the robot were not taken into consideration in the analysis. The videos ranged from 3 to 30 minutes in duration. Participants in the data (N=84) included 10 female pre-primary education teachers and 74 young learners. The parents consents were collected for the children to participate in the study. The young learners and teachers also gave their consent. Unplugged coding and robotics activities are presented in Table 1.

Table 1. *Unplugged Coding and Robotics Activities and Descriptions*

Unplugged coding and robotics activity	Description of activity
Friend coding	Working in pairs or in small groups where some young learners act as the robot and others code the robot, using either: 1. TagTiles, 2. different shaped or coloured plastic pieces, or 3. grid coding mat on the floor to exemplify coding of the KUBO robot.
Sequencing the KUBO robot	Making code sequences individually, in pairs, or in small groups. Different tasks with the KUBO robot:

	1. coding the KUBO to collect as many numbers as possible on grid coding mat filled with numbers,
	2. collecting diamonds and treasures on treasure map, and
	3. free sequencing and experimenting with the KUBO and TagTiles.
Making a short movie with the KUBO	The young learners created a short movie where the KUBO played the leading role. The learners designed a small sequence for the KUBO to act according to their plan. The movies were filmed mainly by the teacher.
Free play with the KUBO	Experimenting and playing with the KUBO robot. One group also used another educational robot for free play.

The analysis conducted for this study was theory-driven and followed the code manual, which was based on the theoretical frame presented in Figure 1. In the code manual, the pre-defined codes were divided in to three domains: emotional support, classroom organisation, and participatory instructional support. These domains were applied from the key theories of TCI and participation (Hamre et al., 2013; Leyva et al., 2015; Pianta et al., 2012, Pianta & Hamre, 2009; Thomas, 2000). The three domains were further divided into dimensions presented in these TCI and participation theories (Figure 1). To conduct the analysis, we used the NVivo12 software (Bryman, 2012; Krippendorff, 2013). The code manual was tested before the analysis by two of the researchers working on the InnoPlay project. In the first phase of the analysis, two researchers analysed the data collaboratively to negotiate and reach a consensus over the interpretation of the videos according to the code manual. The other analyst was the first author who transcribed the data and the third author participated as a field researcher in each of the pre-primary groups analysed. The second author acted as an external evaluator and followed and commented on the discussion when necessary.

First, the units of analysis (n=979) were categorised into domains and dimensions of the theoretical frame (Figure 1). The units of the analysis consisted of two to six phares of dialogue and interaction between a teacher and a young learner. Some units also consisted of the teachers' instructional monologue. In some rarer units, individual words were analysed. These were praise or encouraging comments, such as "*Great!*", which were categorised under the emotional support domain. At the second phase of the analysis, the dimensions of the participatory teacher-child interaction model were read and discussed by the researchers. During the second phase of the analysis, some of the units were detailed and shifted into other dimensions within the domain or relocated to another domain. Also, the results of the two analysts' NVivo coding were compared to one another before compiling the results of the analysis.
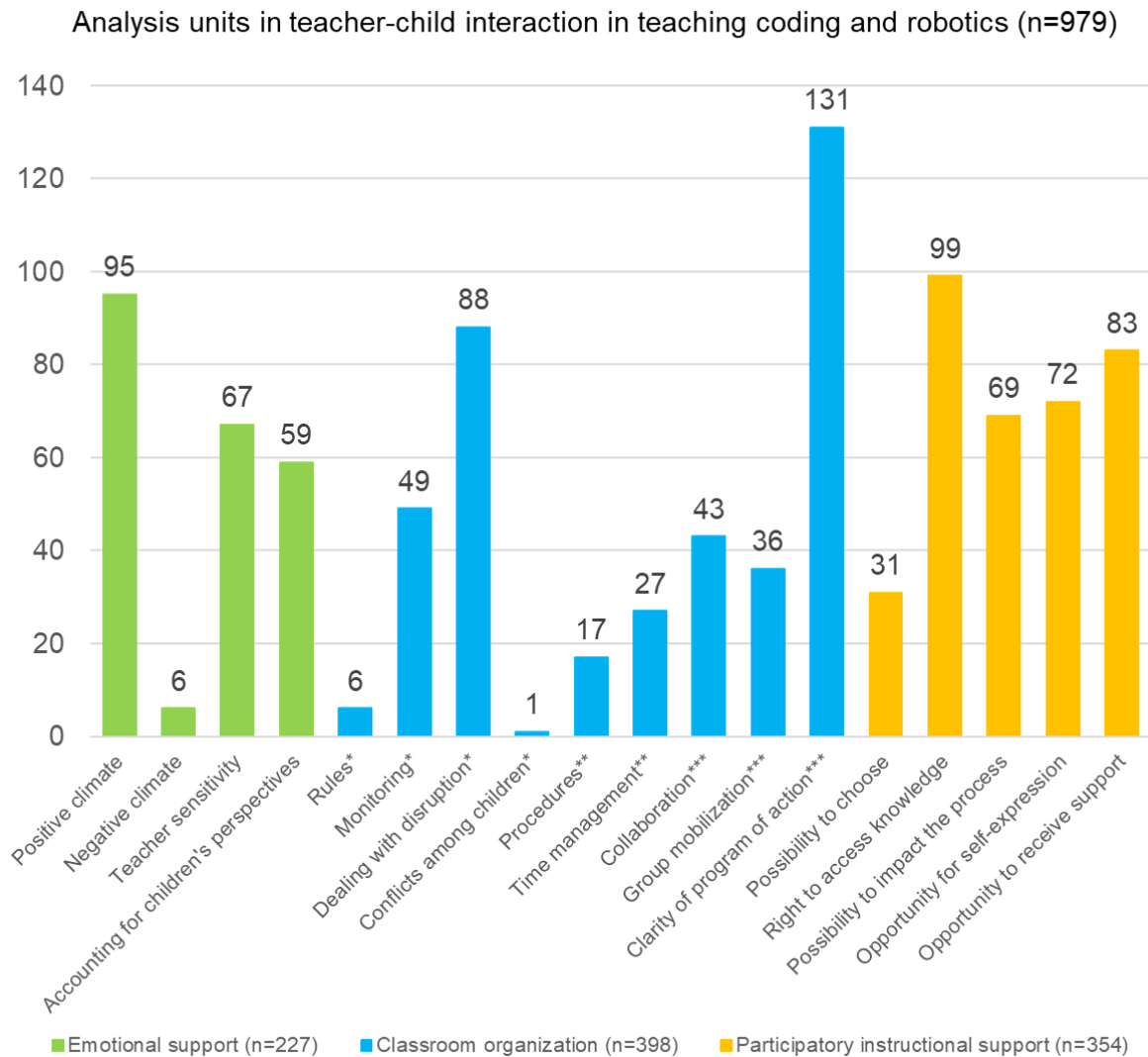

Results

The domains and dimensions of teacher-child interaction in teaching coding and robotics

When teaching coding and robotics, all domains and dimensions of the participatory teacher-child interaction model were recognised in coding and robotics activities. The classroom organisation domain was the most prevalent, and present in all the domains of TCI and found in a total of n=398 units of analysis, covering 41% of the total units. The instructional support domain covered n=354 units and

36% of the total units. The emotional support domain was emphasised the least, covering n=227 units and 23% of the total units (Figure 3).

Analysis units in teacher-child interaction in teaching coding and robotics (n=979)

*   *Behaviour management*
** *Productivity*
*** *Instructional learning formats*

Figure 3.   The units of analysis based on the participatory teacher-child interaction model. The dimensions are presented within the charts of the current domain.

Participatory teacher-child interaction implementation in teaching coding and robotics

Emotional support

In the emotional support domain (Figure 4), the dimension *positive climate* (n=95, representing 42% of the domain) was most prevalent in the analysis. Another dimension of classroom climate, the negative climate, is emphasised (n=6, 3%) of units. The dimensions of teacher sensitivity (n=67, 29%) and accounting for students' perspectives (n=59, 26%) formed altogether over half of the emotional support domain units.

Emotional support on teacher-child interaction in teaching coding and robotics (n=227)
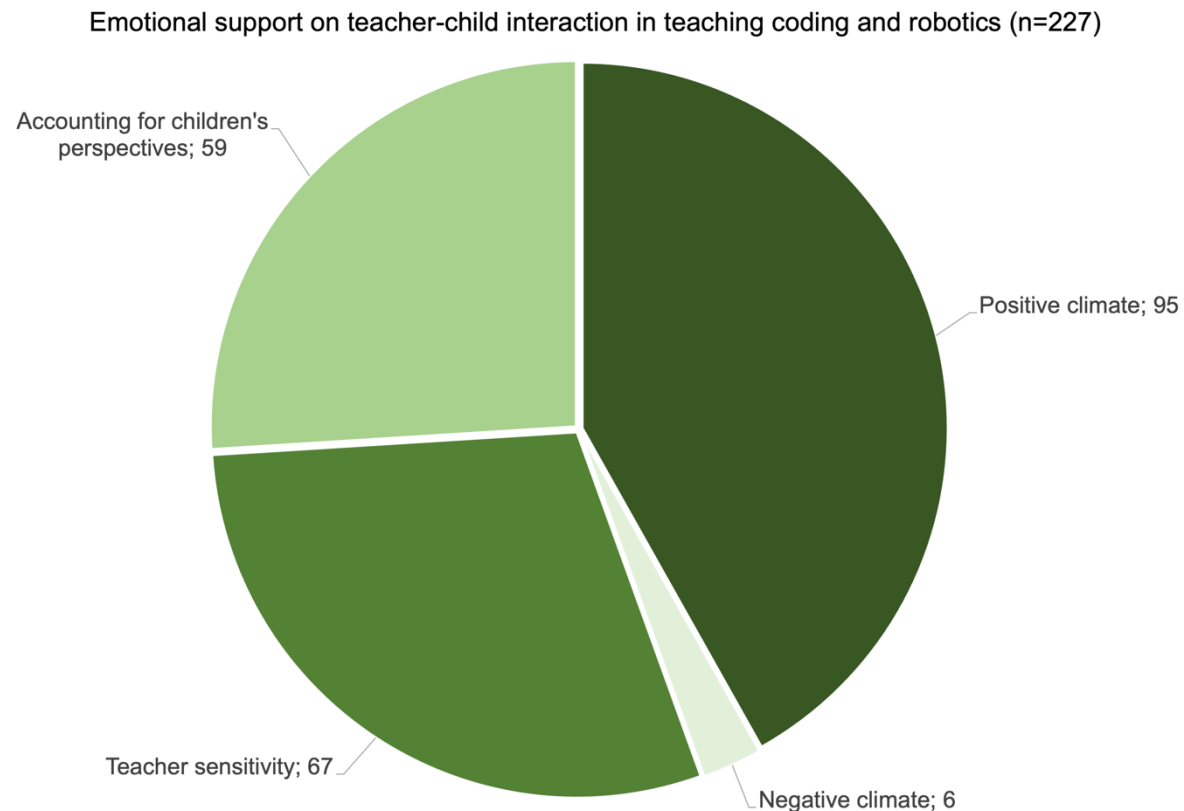
Figure 4.   The emotional support dimensions in hands-on coding and robotics activities in the pre-primary education.

The domain of *emotional support* comprehended the characteristics of participation in coding and robotics. Classroom climate (both positive and negative) and coding and robotics activities were characterised by *kindness, praise, cheering, humour, and positivity.* The positive approach featured also non-content related praise, such as acknowledgments like "*Well done!*" as positive feedback on the young learners' performance. The *negative climate* emphasised both the teachers' and the young learners' frustration expressed when making mistakes, generating negativity, and decreasing young learners' participation.

The teachers showed sensitivity to the young learners individually. A key to participation was the teachers' ability to throw themselves into the coding and robotics activities. For example, in the coding and robotics activity where young learners practised coding with plastic tiles on the floor, the teacher also took part in the action:

> Teacher: Oh, is this for me? [Young learners made sequence based on different shapes and colours.]

Young learner: Yes!

Teacher: Okay. [Steps on the first tile.]

Young learner: Come here! [Waves eagerly to another young learner who hurries to watch.]

Teacher: [Laughs with young learners.] How am I going to make it?

*Young learner: You must go to the end. [Points to the end of the sequence.]*

Teacher: [Acts nervous.]

After this, the young learners gave instructions to complete the sequence and the teacher proceeded at the sequence acting like a robot.

Accounting for the children's perspective dimension emphasised the dialogue between the teacher and the young learners. The teachers strove to engage young learners in participation using reciprocal dialogue by joining the young learners' thoughts and following their lead in the interaction. The teachers showed their own excitement and demonstrated interest in the young learners' thoughts. Occasionally, the teachers had a pedagogical agenda underlying their side of the dialogue. For example, the teachers tried to lead more informal dialogues to promote young learners' thinking. The teachers used formerly learned content to promote young learners' knowledge and to highlight participation by contextualising earlier coding and robotics activities.

Classroom organisation

In *the classroom organisation* domain (Figure 5), the instructional learning formats, which included collaboration (n=43, 11%), group mobilisation (n=36, 9%), and *clarity of programme of action* (n=131, 33%), formed over half of the domain's units. Behaviour management dimensions, including the setting of rules (n=6, 1%), monitoring (n=49, 12%), dealing with disruption (n=88, 22%), and conflicts among students (n=1, <1%) formed approximately one-third of the units. Productivity dimensions, including procedures (n=17, 4%) and time management (n=27, 7%) was emphasised the least in classroom organisation.

Classroom organization in teacher-child interaction of coding and robotics (n=398)
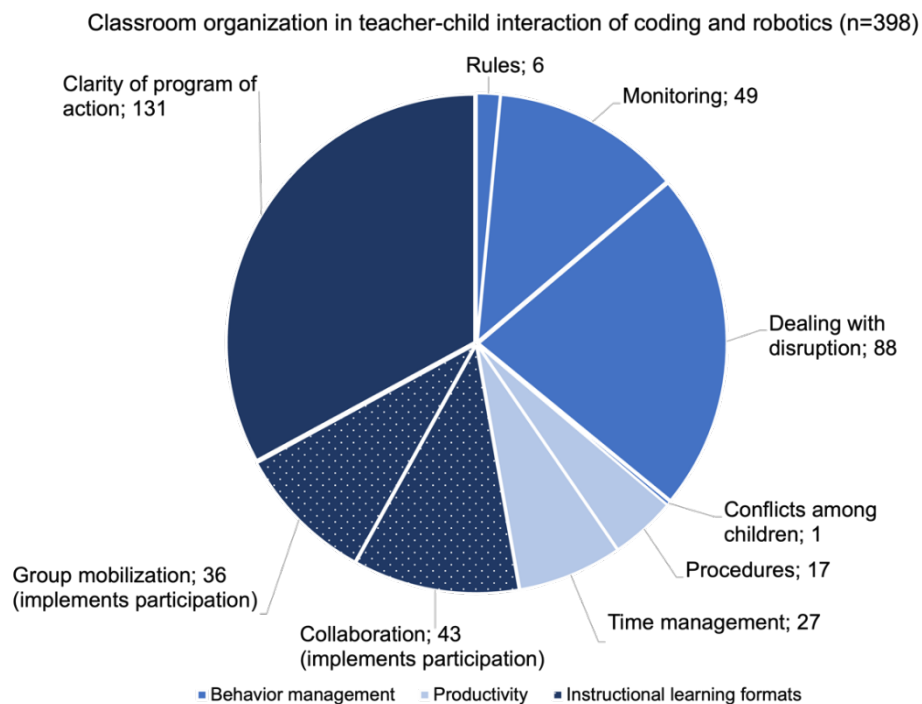
Figure 5.   Classroom organisation dimensions in hands-on coding and robotics activities in the pre-primary education.

Distinctive for the *monitoring* dimension was the teachers' focus on a small group of young learners and then striving to engage as many young learners as possible. For example, in the coding and robotics activities where the teacher taught the principles of coding, she managed to take into account the group as a whole by ensuring every young learner's attention was on the process. Occasionally, the teacher's monitoring led to the interruption of young learners' process for no reason. For example, one teacher rushed to fix a young learner's sequence only to realise that the young learner had made the sequence correctly.

The *dealing with the disruption* dimension emphasised the teachers' actions directed towards dealing with disruption during the   coding and robotics related content of the lesson. The key responsibility for resolving the disruption was the teachers. The teachers used various strategies for dealing with the disruption and re-engaging young learners with the coding and robotics activity. For example, the teachers made suggestions to young learners on how to fix problems but also debugged some problems by themselves, decreasing the young learners' participation.

In the instructional learning formats dimension *collaboration,* the teachers gave space for young learners' engagement and participation. That was seen in the teachers' sensibility to not intervene too easily in the young learners' coding and robotics activities. The units of analysis in the working alliance dimension exemplified the teachers' actions aimed to encourage young learners to collaborate and thus participate themselves in the coding and robotics activity. In the *group mobilisation* dimension, units emphasised the teachers' actions aimed at engaging young learners with the task at hand. These units consisted of dialogues between the teacher and two or more young learners. The teachers strove to maintain the groups' focus by activating them with the dialogue. For example, in a space-themed activity where young learners had time to freely play with the robot, the teacher organised the play by engaging the young learners thus:

> *Young learner: [The robot starts to spin.] It is drawing the sun!*
>
> *Teacher: Great! I think the others [robots] sent the message to the earth and called them to join.*
>
> *Young learner: Now the other one! [Points out another robot.]*
>
> *Teacher: Please, give it to [name] so [name] can try it. Just put it somewhere in the space.*

Occasionally, the teachers tried to instruct multiple things simultaneously which led to situations where the given instructions were difficult to understand, and the young learners' participation suffered. For example, on one occasion during the friend coding activity, where the group size was 12 young learners, the teacher tried to give instructions to five young learners at the same time.

The *clarity of the programme of action* dimension exemplified moments in TCI where participation was lacking. A distinctive feature of the clarifying actions was that they were teacher oriented. The teachers led the ongoing process using monologue or by demonstrating activities hands-on. They strove to keep lessons running fluently by clarifying instructions. For example, in the friend coding activity, instead of learners coding in pairs, the teacher led the process:

> *Teacher: Five squares [name]. [The young learner advances on the coding mat.] One, two, three, four, five. Good, please stay there and let the letter E lay down on the ground. Just step on top of it. Let's move it little bit. [Moves the letter in the square.] Please stay in the centre of the square.*

Clarifying instructions given by the teachers were often negative, such as "*Don't open the KUBO's box!*" The teachers anticipated the process by telling the young learners straightforward the next steps in the coding and robotics actions. For instance, this appeared in the film making activities where the

teacher clarified to young learners that the KUBO robots first need to be programmed and after that the movie scenes are ready to be filmed.

Participatory instructional support

In *instructional support* (Figure 6), children's right to access knowledge (n=99, 28%) was emphasised the most. Three of the dimensions were emphasised rather evenly: learners' possibility to impact to activities (n=69, 19%), self-expression (n=72, 20%), and opportunity to receive support (n=83, 23%). The dimension of having the possibility to choose was recognised (n=31, 9%) the least.

Participatory instructional support in teacher-child interaction of teaching coding and robotics (n=354)
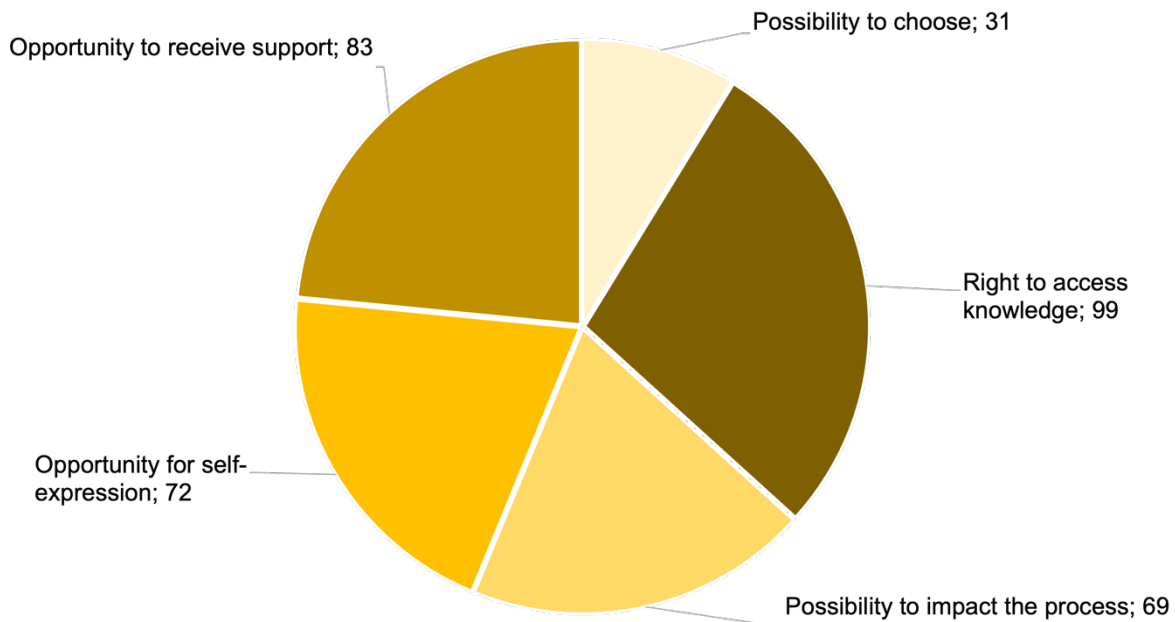
Figure 6. **Participatory instructional support dimensions in hands-on coding and robotics activities in the pre-primary education.**

The dimension titled *the possibility to choose* emphasised young learners' autonomy in TCI. The teachers asked for young learners' opinions on which roles they wanted to participate in during the coding and robotics activities. For example, during friend coding the teachers constantly gave children the opportunity to choose whether they wanted to act as a robot or to be a coder. The choice was sometimes also misleading when the teachers led young learners to choose in a way that the teachers preferred. The teachers formed leading questions which led the young learners to choose the answer the teachers wanted them to. Questions were frequently dichotomic such as "*Which way does the robot have to turn now left, or right?*" These questions did not engage the young learners in the coding and robotics activities.

In the dimension titled *the possibility to impact the process*, the teachers engaged the young learners in the decision-making processes by encouraging them to explore and experiment with the robot. Experimenting was supported by the teachers' statements such as "*get to know the robot*", or "*see what happens*". The following exchange is a good example of TCI endorsing experimentation with the robot as a young learner explored the KUBO robot and how to sequence it:

> *Young learner: Hey, now I get it! Can the robot go like this? [Puts two turning TagTile pieces one after another.].*

> *Teacher: Try it out to see what happens.*

> *Young learner: Like this? [Puts the robot down to run the sequence.]*
>
> *Teacher: Yes. [Robot turns twice and stops. Young learner snatches the robot.]*

Key elements in giving young learners *the possibility to express their thinking* included authentic listening and being present during the interaction. Such acts on behalf of the teachers' gave enough space for the young learners' cognitive activity and guided them towards higher-order thinking. The child-centred approach could be seen in how the young learners reflected on what they witnessed with the robot. Simultaneously, the teachers enhanced engagement through interaction by listening to what the young learners were saying.

The teachers managed to interact with the young learners in a way that sparked and stirred the learners' thoughts, opinions, and feelings. The teachers asked questions about the young learners' process, such as "*How did you give the instructions to the robot?*", which gave young learners the chance to express their own thinking. In relation to the opportunity to receive support, the teachers strove to engage young learners by leading them towards the knowledge and by encouraging the learners to express their views. The teachers gave cues rather than straight answers to young learners. Occasionally, the young learners did not fully understand the teachers' instructions when the process turned teacher-oriented and the teacher did not invite the participation of the young learner.

Conclusions and discussion

The current study examined participatory TCI in teaching coding and robotics to young learners in pre-primary education. All domains of TCI, including emotional support, classroom organisation, and participatory instructional support, were recognised in the analysis. The results indicate that, in pre-primary education settings, classroom organisation is emphasised most in TCI (Figure 5). Within the classroom organisation domain, the dimension for *the clarity of the programme of action* was emphasised most and was also the most frequently recognised dimension in the data (Figure 3). It emphasised the teacher-oriented actions which, considering participation, decreased the young learners' own experimentation. Nevertheless, teacher-oriented actions were sometimes obligatory to achieve the hoped outcomes of the coding and robotics activities. Also, in terms of advancing technological literacy the instructions and scaffolding by the teacher were found relevant for participation. Emotional support and especially *positive classroom climate* were also found to be the fundamental aspects of participation. Figure 7 illustrates the characteristics of participatory TCI highlighted in the analysis that were seen enhancing young learners' participation.
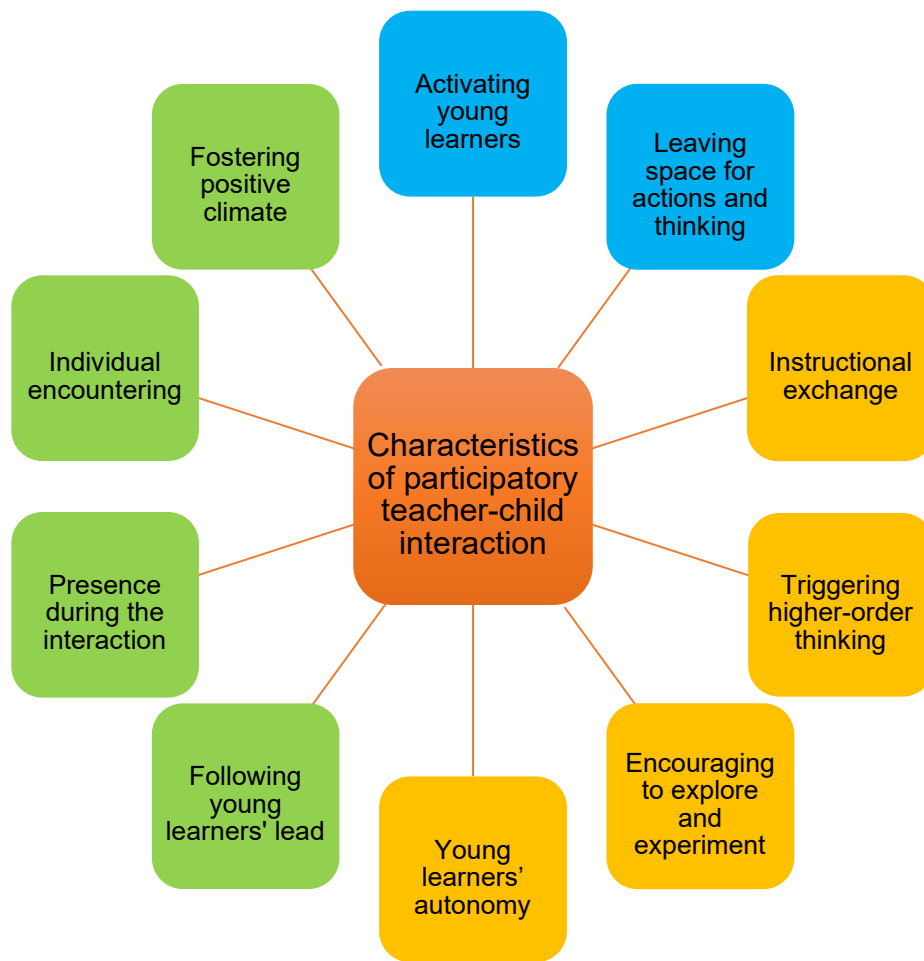
Figure 7. Characteristics of participatory teacher-child interaction in teaching coding and robotics in pre-primary education. Emotional support on green, classroom organisation on blue, and participatory instructional support on orange.

In the analysis, the participatory teacher-child interaction framework (Figure 1) with its domains and dimensions was used as a coding manual in recognising units of analysis in the data that included open-ended learning activities which required problem-solving in coding and robotics. With the efforts of three researchers, the notations could be divided into the three domains of TCI and further placed into the dimensions as sub-categories (Figure 3). Using the theory-based analysis (Krippendorf, 2013), only a few notations had to be negotiated and relocated following the researchers' discussion so that a shared understanding was reached. The study presents descriptive statistics   addition to its qualitative results. These figures (4, 5 & 6) clearly depict the number of teachers using either emotional or instructional support or classroom organisation and the related dimensions. Thus, the results cannot be generalised without further research on the participatory TCI model in pre-primary education. The results of the study represent the current state of technology education and teaching coding and robotics in six groups in the Finnish pre-primary education. However, the use of the participatory TCI theoretical framework in the analysis (Figure 1) verifies that it could be implemented well in gathering notions from the data. It is therefore possible that the framework could be used as a model to advance and study TCI in open-ended learning activities not only in pre-primary education but also in primary and secondary levels.

All in all, 67% (n=660) of all units (N=979) of analysis including emotional support, participatory instructional support, and classroom organisation with the dimensions of *collaboration* and *group mobilisation* emphasised participatory TCI. To increase the trustworthiness of the results, the data represented TCI precisely in coding and robotics activities from six different pre-primary education groups with 74 young learners taking part and being guided by 10 teachers. The data was collected and

managed following the guidelines set by the Finnish National Board on Research Integrity (TENK, 2019).

The characteristics of participatory TCI (Figure 7) can be considered as didactical elements used to enhance teaching and learning coding and robotics and overall open-ended problem-solving activities. In this sense, coding and robotics offer solutions to the concern raised by Svensson and Johansen (2019) who state that a teacher's didactical methods in technology education do not provide enough support for technology learning. For teachers who recognise the domains and dimensions of TCI and use them actively, this might offer diverse didactical methods (Avsec & Szewczyk-Zakrzewska, 2017) that have the potential to enhance technological knowledge and literacy of a wide range of children. Based on current analysis (Figure 3), it appears that with participatory TCI, a teacher can bring an added value to the technology education of young learners. In this sense, participatory TCI should be included in pre- and in-service teacher education and training. It is important to note that while participatory TCI could be used as a method to enhance technology teaching and learning, coding and robotics seems to offer an environment for participatory TCI in hands-on work as well.

According to Pianta et al. (2012), a focus on instructional exchanges in classroom settings was considered devoid of personal, emotional, and motivational properties that would engage the children in the task at hand. Thus, the current results indicate that coding and robotics activities in pre-primary education with individual, emotional, and motivational interaction and instructional exchanges play a major role in supporting participation. According to Grönman et al. (2022), the needs of various character types of learners are different for TCI. However, if learners are supposed to be active in coding and robotics activities, the teachers' role shifts from leading and teaching to supporting and scaffolding the process (Alimisis, 2018). Based on the current results (Figure 7) we can consider that, by enhancing participatory TCI in teaching coding and robotics, the teachers can support young learners' autonomy, exploration, and experimentation. Most teachers show children strong emotional support and can encounter them individually, which Grönman et al. (2022) found to be important for all character types of learners in technology education.

The *clarity of the programme of action* (Figure 3) was the most frequently recognised dimension in the data. It emphasised the teacher-oriented actions which decreased the young learners' participation and own experimentation. To conclude, teacher-oriented actions and guiding the classroom activities expressed both the teachers' and young learners lack of skills on coding and robotics. While working with young learners, the focus on participation is situational. Sometimes teacher-oriented approaches are more efficient or even mandatory for ensuring that young learners understand the given instructions clearly. Also, as seen in the literature, the non-participatory teacher has little flexibility, follows daily plans strictly, shows little response to children's interests, and does not provide children with many opportunities for self-expression (Pianta et al., 2012). However, to support different learners and their learning orientations, such as the character types of different learners described by Grönman et al. (2022), the emotional support and participatory instructional support should be investigated more. The current results depicting the characteristics of participatory TCI (Figure 7) indicate that recognising these characteristics in young learners' coding and robotics activities can enhance their technological literacy.

The results can be used and implemented in teacher education and especially in teacher training where pre- or in-service teachers practise open-ended problem-solving like coding and robotics. The participatory instructional support view in the data revealed that if the teacher instructed young learners mechanically and did not consider their ideas, thoughts, and suggestions, the participation of the learners decreased. To be able to consider a child's ideas, thoughts, and suggestions, a teacher must have pedagogical content knowledge in technology education. According to current results, without pedagogical content knowledge it is challenging to enhance young learners' participation. If the teacher cannot engage or encourage young learners to participate in learning (Thomas, 2000), they will follow the teacher's instructions strictly. This will make learning convergent and mechanical instead of promoting young learners' agency. Participatory instructional support could ensure that the open-ended learning activities are carried out non-mechanically.

A discussion on the strengths and weaknesses of this study should consider its realisation. The domains of the participatory TCI (Figure 1) were found to overlap each other somewhat, so that the units of analysis could have been coded differently. Previous research has found that three domains are distinctive yet interrelated domains of the TCI (Leyva et al., 2015) and that a single domain on its own may not be enough for depicting TCI (Pianta et al., 2012). In this study, the dimensions were also found to intertwine. For example, teachers' ability to throw themselves into the process of engaging young learners and emphasising a positive climate in the classroom. This shows how the teacher sensitivity dimension was found to closely relate to the positive climate dimension.

Moving from the teacher-oriented teaching of coding and robotics to participatory TCI, the teachers' individual pedagogical content knowledge should be considered. The need for enhancing teachers' specific pedagogical content knowledge in technology education has been recognised in pre-service teacher education (Mahmud et al., 2018). Simultaneously, teachers' skills in perceiving children's thinking and ideas are necessarily interwoven with teachers' skills of attending to and regulating the emotional, social, and motivational aspects of interaction (Metsäpelto et al., 2021). Concluding the discussion of our findings, it appears that teachers' competence in coding and robotics seem to be extremely relevant for participatory TCI that engages a young learner individually in the coding and robotics activities. Without pedagogical content knowledge of coding and robotics teaching young learners in a way that supports their participation, higher-order thinking and learning of technological literacy seems problematic. The results of the current study suggest that the relation between participatory TCI and the teachers' pedagogical content knowledge of coding and robotics should be further investigated in the future. For example, to enhance participatory TCI in coding and robotics activities, longitudinal research on development of teachers' pedagogical content knowledge might produce results that can advance technology education of young learners and further develop their technological literacy.

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