



Teaching technology to young learners: teachers' individual competencies

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Abstract

Introducing technology education (TE) at an early age is essential in today's digital world. It is not only important to teach students how to use technology but also to cultivate technological literacy, which is critical in increasingly technology-driven societies. Teachers play a pivotal role in enhancing the technological literacy of young learners (ages 5–8 in this study), and they require specific competencies to integrate technology into their daily practices across various educational settings. This study investigates the key individual competencies that teachers need to conduct TE for young learners by focusing the experiences of 12 teachers who participated in in-service TE training and conducted various craft, design, and technology (CDT) and science, technology, engineering, arts, and mathematics (STEAM) projects in their classrooms. The study uses the multidimensional adapted process (MAP) model for teaching as its theoretical basis; this model includes the individual and teaching competencies needed by teachers. The findings reveal that teachers must possess both a knowledge base and personal orientation towards technology. These two include different competencies—such as pedagogical content knowledge (PCK) and self-efficacy—that are interrelated and essential for conducting TE projects with young learners. Based on these findings, the study proposes a framework outlining the key individual competencies needed for providing TE to young learners. The framework aims to enhance the professional development of teachers in their initial teacher education and in-service training. We propose that future research should utilise this framework to promote TE that fosters technological literacy among young learners.

Keywords Young learners · Technology education · Teacher competence · Individual competencies · MAP model · Technological literacy

Introduction

The digitalisation of society and constant evolution of technology has required the provision of sufficient technology education (TE) to students at all levels—and, accordingly, the in-service training of teachers in TE. The ongoing technological reformation

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demands teachers, even of the young learners (5–8 years old), to shift teaching increasingly towards technology orientation (Casillas Martin et al., 2020; Kara & Cagiltay, 2017). For long, it is recognised that more expertise for young learners TE is needed (Turja, et al., 2009), and current technological trends, such as artificial intelligence, increase this need (Falloon, 2024). The main educational goals in TE include imparting factual knowledge of technological content and developing transferable skills and knowledge to enhance learners' technological capabilities (Doyle et al., 2017). TE and science, technology, engineering, arts, and mathematics (STEAM) have been recognised as being able to enhance young learners' curiosity, creativity, co-operation, and critical thinking (Bers et al., 2019; Gardner et al., 2019; Lottero-Perdue, 2020), which are all vital 21st-century skills (Deák & Kumar, 2024). Modern society demands both competences to use technology as a tool for learning (Korhonen et al., 2023) and technological literacy (International Technology and Engineering Educators Association [ITEEA], 2020). Technological literacy consists of the skills required to use, understand, create, and critically assess technologies (Garmire & Pearson, 2006; ITEEA, 2020).

The lack of competency in teaching digital and technological content among pre-service teachers has been noted in recent research, highlighting their need for professional development (Casillas Martin et al., 2020; Lottero-Perdue, 2020; Park et al., 2017). It has also been indicated that pre-service teachers have misconceptions and shortcomings in their own understanding of technology (Kurup et al., 2017). At the same time, teachers' understanding of TE is essential in preventing learners' misconceptions of technology (Rohaani et al., 2010), and without proper content-specific knowledge, teachers are struggling to teach technology in a way that triggers young learners' thinking (Korkeaniemi et al., 2023; Svensson & Johansen, 2019). To investigate and develop initial teacher education and teachers' professional competencies, the multidimensional adapted process (MAP) model was developed in a national co-operation among seven Finnish universities (Metsäpelto et al., 2020, 2021). In the MAP model, teacher competencies are understood as the knowledge, skills, and resources that explain teachers' effectiveness in their profession (Metsäpelto et al., 2021). Earlier research has used the technological pedagogical content knowledge (TPACK) model, which describes the knowledge that teachers need to integrate technology into their teaching (Mishra & Koehler, 2006). While the TPACK model has similarities to the MAP model with regard to the knowledge base of teachers, the MAP model also emphasises the personal orientations of teachers.

Young learners' TE involves the teaching and learning of technology through a project-based approach, which is a common pedagogical approach in a young learner educational setting (Bers, et al., 2019; Kangas et al., 2022; Sormunen et al., 2023). Research into young learners' TE has thus far focused on teachers' use of different technologies as tools for teaching and learning (Veličković & Stošić, 2016). Prior research has also investigated technological content and hands-on activities from the perspective of both teachers and young learners. This has included concepts such as using different artefacts and systems (Bourbour & Masoumi, 2017; Brown et al., 2016; Sundqvist, 2020), and coding and educational robotics (Chaldi & Mantzanidou, 2021; Kyza et al., 2021; Papadakis, 2021). Research has also focused on technological contents in curriculums of teacher training (Alimisis, 2018) and young learners' TE (Turja et al., 2009). Still, research into the competencies that teachers need in young learners' TE—that is, in creating a setting where young learners are active agents who are using, interacting with, creating, and exploring technology by themselves—is lacking. Also, there is an absence of a particular focus on technological literacy in its broader sense.

In Finland, every child has a subjective right to participate in communal early childhood education and care (ECEC) with a cost adjusted according to the family's income, before mandatory, free-of-charge pre-primary and basic education. Pre-primary education starts at the age of six, and basic education at age of seven. TE has now been introduced nationally in the Finnish curriculum for ECEC (Finnish National Board of Education [FNBE], 2022) and in the curriculum for pre-primary education (FNBE, 2016) as a skill necessary for managing daily life. In the curriculum covering young learners participating in the first two years of basic education, TE is introduced as a part of the school subject of craft, design, and technology (CDT) (FNBE, 2014). In the international context, CDT as a subject is closely related to STEAM education.

In this study, TE refers to the context of young learners' CDT and STEAM education and projects conducted as part of the 2018–2022 InnoPlay project.

The InnoPlay project was one of the key projects reforming teacher education and young learners' TE under the Ministry of Culture and Education in Finland. One of the aims of the project was to prompt teachers of young learners to enhance technological literacy through practical, hands-on learning activities. In these learning activities, TE was integrated in a way that emphasised young learners' experimentation, play, and expression. The following research focuses on teachers' experiences of providing TE to young learners. The aim is to map the key individual competencies that teachers need when facilitating young learners' TE, and to produce new knowledge for enhancing the teaching of technological literacy to young learners. Specifically, this study seeks to answer the research question, "What individual competencies are relevant in teachers' experiences of providing TE to young learners?"

Theoretical background

As Korthagen (2004) states, an attempt to describe the essential qualities of a good teacher should consider that various levels are involved that fundamentally differ from each other. Thus, instead of seeking the qualities of good teacher, this study focuses on identifying the individual competencies that contribute to the necessary knowledge and skills needed in young learners' TE. Teachers' individual competencies include a combination of knowledge, skills, attitudes, values, and personal characteristics, empowering them to act professionally and effectively in situations involving teaching and children's learning (Koster & Dengerink, 2008). In TE and the integration of digital content into the teaching of young learners, teachers' competencies have been recognised as lacking (Aldhafeeri et al., 2016; Kara & Cagiltay, 2017; Palaiologou, 2016). The MAP model aims to specify and illustrate key competencies that are critical for the teaching profession in its wider sense (Metsäpelto et al., 2020, 2021). In the MAP model, teacher effectiveness is based on student outcomes, such as academic achievement and skills (Metsäpelto et al., 2021). However, as the current study aims to gain insight into teachers' individual competencies rather than young learners' academic achievement, teacher effectiveness is not considered in this study. The MAP model (Metsäpelto et al., 2021) is divided into two main domains: individual competencies and teaching competencies, as illustrated in Fig. 1.

The theoretical framework for this study is further adapted to find the key individual competencies needed in the TE of young learners. Earlier research has recognised that a sufficient knowledge base is essential for providing TE to young learners (Bjursten et al., 2023; Hatzigianni et al., 2024; Wang et al., 2024). Also, teachers' personal orientations,

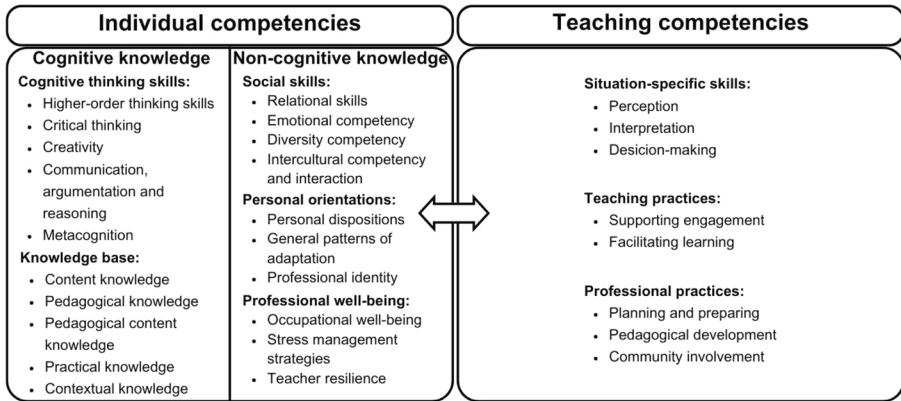


Fig. 1 Teachers’ individual and teaching competencies (adapted from Metsäpelto et al., 2020, 2021)

such as their values, beliefs, attitudes, motives, participation in in-service training, and professional development, have been found to be relevant (Hatzigianni et al., 2024; Havice et al., 2018; Seery et al., 2018). In this study, the MAP model is thus used for mapping teachers’ key individual competencies—including their knowledge base and personal orientations—in facilitating young learners’ TE. The integration between personal orientations, such as self-efficacy beliefs about teaching and learning technology, and knowledge base, such as pedagogical content knowledge (PCK), has been in focus in TE research (Abbitt, 2011; Doyle et al., 2019a, 2019b). The investigated individual competencies of knowledge base and personal orientations in young learners’ TE are introduced in the theoretical framework (Fig. 2).

Knowledge base

Many knowledge systems have been recognised as fundamental to teaching, such as the knowledge of students’ thinking and learning, and knowledge of the subject matter (Mishra & Koehler, 2006). In the MAP model, teachers’ individual competencies are further

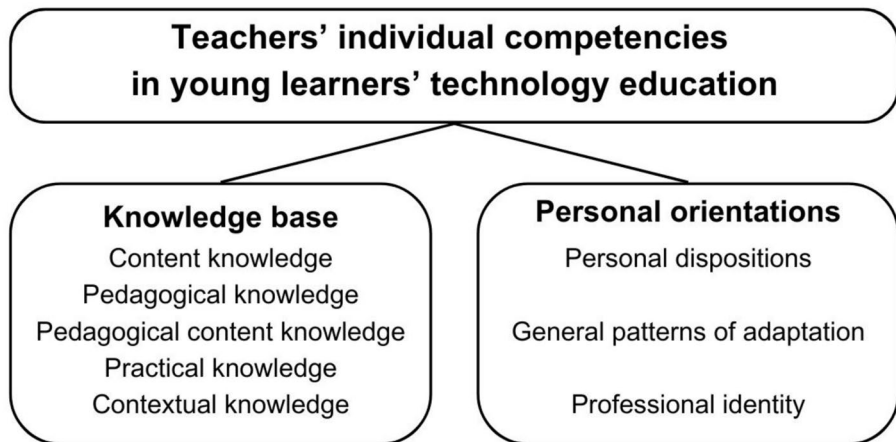


Fig. 2 Theoretical framework: teachers’ individual competencies in young learners’ TE (adapted from Metsäpelto et al., 2020, 2021)

divided in cognitive and non-cognitive knowledge and skills (Metsäpelto et al., 2020). Klassen et al. (2018) distinguished between cognitive and non-cognitive attributes as follows: cognitive knowledge relates to the sub-domain of knowledge base, while non-cognitive knowledge relates to personal orientations; both are considered relevant in the teaching profession (Metsäpelto et al., 2021). *Knowledge base* is defined as the 'aggregation of knowledge, skill, understanding, and technology, of ethics and disposition, of collective responsibility—as well as a means for representing and communicating it' (Shulman, 1987, p. 4). In the MAP model, the knowledge base for teaching and learning is divided into five categories: content knowledge, PCK, practical knowledge, and contextual knowledge (Metsäpelto et al., 2021).

Content knowledge has long been recognised as a key element of teachers' knowledge. It includes the knowledge and skills that need to be taught to students (Mishra & Koehler, 2006; Shulman, 1987)—that is, the knowledge itself and its organisation in teachers' minds (Shulman, 1986). Content knowledge further includes the understanding of the curricular content (Baumert et al., 2010) and its scope and disciplines (Shulman, 1987). By nature, it is made up of facts and concepts relevant to the subject matter, which will create new knowledge in students (Ball et al., 2008; Shulman, 1986). In teaching, this comprehension covers the understanding of both what to teach and when to teach it (Shulman, 1987). For example, past research has demonstrated that to improve computational thinking in the classroom, teachers need to be able to think computationally themselves (Mahmud et al., 2018). Also, in teaching coding and robotics, teachers need a certain amount of content knowledge to pose questions that trigger young learners' thinking (Korkeaniemi et al., 2023). In addition, Hasse (2017) identified that teachers' technical skills can be transferred to enhance students' understanding and comprehensive technological literacy in TE.

Shulman (1987) refers to *general pedagogical knowledge* as the broad principles and strategies of organising and managing the classroom. It is the deep knowledge of the processes of teaching and learning, encompassing educational purposes and aims (Mishra & Koehler, 2006). It also emphasises classroom events at different levels, including knowledge of classroom management and knowledge of students' individual characteristics and learning processes (Voss et al., 2011). A teacher with deep pedagogical knowledge understands students' construction of knowledge and skills (Mishra & Koehler, 2006). Pedagogical knowledge further includes the structure and assessment of classroom events and teachers' understanding of the factors regulating learning, such as motivation (Guerriero & Révai, 2017). Pedagogical knowledge can also refer to the instructional selection and repertoire formulated by teachers to present the content through different representational forms (Shulman, 1987); it can also be referred to as the knowledge of teaching methods (Voss et al., 2011). Pedagogical knowledge involves the transformation of ideas to teaching, including the preparation of different materials, the representation ideas through forms such as analogies and metaphors, the selection of teaching methods, the adaptation of representations to the characteristics of children, and the targeting of these adaptations to the children individually (Shulman, 1987).

Traditionally, teacher knowledge has been separated into the concepts of content knowledge and pedagogical knowledge (Mishra & Koehler, 2006). Combining these, however, *PCK* focuses on the various methods available for teaching a specific subject and for adapting teaching to match students' specific abilities and needs (Blömeke, 2017; Shulman, 1987). *PCK* represents teachers' special form of professional knowledge (Shulman, 1987) that covers their understanding of students' prior knowledge and of what makes concepts easy or difficult to learn (Blömeke, 2017; Mishra & Koehler, 2006). However, *PCK* also encompasses the knowledge of teaching materials and curricula (Blömeke, 2017), which

makes its distinction from content knowledge difficult. Teachers need to rationalise the content they are teaching and adjust their pedagogical techniques to promote students' own understanding and examination (Gess-Newsome et al., 2017). As such, content knowledge and PCK both relate to subject-specific knowledge, but they approach it from different perspectives (Blömeke, 2017). The source of PCK is teachers' specific experiences relevant to TE (Doyle et al., 2019b; Wang et al., 2024). Therefore, it can be described as teachers' pedagogical know-how formed through years of teaching experiences, creating processes that they employ in their teaching (Shulman, 1987). Mishra and Koehler (2006) introduced the concept of TPACK, which integrates content pedagogy and technology to form a basis for good teaching with technology. In young learners' TE, TPACK is relevant because the teaching of technological content requires teachers' individual content-specific knowledge (Korkeaniemi et al., 2023; Sundqvist, 2020; Veličković & Stošić, 2016).

Practical knowledge is related to handling dilemmas and challenges faced in the classroom (Cochran-Smith & Lytle, 1999) and includes the implicit and tacit knowledge gained from teaching experiences (Metsäpelto et al., 2020). Shulman (1987) refers to *practical knowledge* as the 'wisdom of practice' that creates the standards for teachers' future practices. According to Veličković and Stošić (2016), to teach technological content, such as using computer programmes, teachers need practical experience working with young learners. *Contextual knowledge* refers to the sociocultural setting in which teaching occurs. This includes adjusting teaching to the broader purposes and values of education, such as the local community and society (Metsäpelto et al., 2020). It ranges from the group level in the classroom to the cultural and societal aspects of education, including knowledge of educational values, purposes, and ends (Shulman, 1987). Contextual knowledge involves the critical understanding of the cultural factors that shape education in the community context (Darling-Hammond, 2006). It is also included in the TPACK framework to promote teachers' understanding of the learning context and their role as intrapreneurs who know how their organisations function (Brianza et al., 2024; Mishra, 2019).

Personal orientations

The sub-domain of *personal orientations* involves teachers' management of their own role (Metsäpelto et al., 2020, 2021). The ongoing shift in teachers' role from 'deliverer of knowledge' to 'facilitator of learning', and from a subject specialist to teacher of individuals is being accepted by teachers themselves (Biesta et al., 2015). This is further emphasised as children are exploring technological activities and roles by imitating them (Turja et al., 2009), and as the participatory interaction between teachers and young learners is acting as a mediator in this exploration (Korkeaniemi, et al., 2023). Past research has indicated that proper in-service training could enhance the provision of TE and the teaching of STEAM by emphasising efficacy and eagerness to work on different projects (Hatzigianni et al., 2024; Wang et al., 2024). Personal orientations refer to the continuous evolution of individual and motivational characteristics, with one's identity acting as a teacher (Metsäpelto et al., 2020). In the MAP model, personal orientations are divided into three categories: personal dispositions, general patterns of adaptation, and professional identity.

Personal dispositions describe the differences between one's thoughts, behaviours, and emotions, which account for one's functioning in different situations and over time (McAdams & Pals, 2006). Similarly, personality is an individual's variation of the evolutionary design of human nature expressing the development pattern of dispositional traits (McAdams & Pals, 2006). Personality can be divided into five domains, known as

the “Big Five”: extraversion, agreeableness, conscientiousness, neuroticism, and openness (John et al., 2008, p. 115). Teachers' personality has been found to be positively associated with their teaching effectiveness (Kim et al., 2019; Klassen & Tze, 2014). Dispositional traits represent the ways in which a person does things, feels about things, and typically thinks (McAdams & Pals, 2006). In the teaching profession, these traits and personality characteristics have been known to influence teachers' decisions and behaviours (Shavelson & Stern, 1981). This agency is seen as an important dimension of teachers' professionalism (Beijaard et al., 2004; Biesta et al., 2015).

The *general patterns of adaptation* include variations in the ways in which teachers adjust to different situations, contexts, and roles in different phases of their careers (Metsäpelto et al., 2020). The MAP model accounts for these individual adaptations to the teaching profession by including the following dimensions: self-efficacy, professional beliefs, values, ethics, motives, and interest towards teaching and learning (Metsäpelto et al., 2021). When integrating technology into young learners' education, teachers' self-efficacy and attitudes are of particular importance (Abbitt, 2011; Merjovaara et al., 2024; Peretti et al., 2024). Teachers are exhibiting autonomy and confidence when they integrate technological content, such as computational thinking and coding, into the STEAM education they provide (Bers et al., 2019). These characteristic adaptations, such as their beliefs, include many different aspects of human individuality, such as self-image, schemas, virtues, goals, plans, strivings, and strategies (McAdams & Pals, 2006). However, prior research has focused mainly on teachers' beliefs, engagement, and commitment rather than on their self-efficacy (Klassen & Tze, 2014). Beliefs and values are seen as aspects of the professional knowledge that teachers bring to their work (Biesta et al., 2015; Liejen et al., 2020). In TE, the importance of teachers' ability to build and synthesise content-specific attitudes has also been recognised (Seery et al., 2018), as this can have either positive or negative impact on how they integrate technology into the educational setting for young learners (Lim et al., 2024; Mertala, 2019; Peretti et al., 2024). These beliefs are multi-faceted and can relate to teachers' beliefs about children, about teaching, and about their own educational purpose (Biesta et al., 2015), as well as to their beliefs about the role of technology in education (Abbitt, 2011; Jääskelä et al., 2017).

Professional identity is not something that teachers use to identify themselves as teachers through an ongoing process of understanding themselves as professional actors (Beijaard et al., 2004). It includes a range of knowledge and a repertoire of behaviours and skills that are needed to practice the teaching profession (Guerriero & Deligiannidi, 2017). Teachers' professional identity is not completely unique, however, as they are expected to act and think professionally through prescribed characteristics, such as acquiring certain knowledge and exhibiting certain attitudes (Beijaard et al., 2004). Therefore, it is mixture of knowledge base, personal dispositions, and general patterns of adaptation connected to one's individuality. McAdams and Pals (2006) also recognised developmental tasks as an aspect of human individuality. Teachers are expected to constantly develop and update their knowledge and follow the models of others (Cochran-Smith & Lyttle, 1999). Therefore, it is suggested that professional development should focus on developing 'habitual ways of thinking about schooling and to encourage an innovative and questioning mindset' (Priestley et al., 2016, p. 31). At an organisational level, it is recognised that ECEC centres with an overall positive view of STEAM education are able to discuss and implement it within their organisations (Tippett & Milford, 2017). Thus, Toom et al. (2010) suggested that continuing professional development is a key part of teacher education that is closely related to teachers' motives and interests.

Methodology

As this study aimed to investigate teachers' experiences, it used a phenomenological approach (Spencer et al., 2020). Participants (N=12) reflected on their experiences of providing TE to young learners and participating in in-service TE training within the InnoPlay project. At the time of the study, participants were working with young learners in pre-primary education and the first two years of basic education in two schools and four ECEC centres (Table 1).

The data was collected at the end of the InnoPlay project and consisted of six interviews. The semi-structured interviews were conducted after the teachers had finished their TE projects and in-service training within the InnoPlay project. The interviews could be described as 'a conversation with a purpose' (Kahn & Cannell, 1957, p. 97) because of their semi-structured nature. To investigate authentic experiences, the interviewers provide space for unstructured reflections (Prior, 2020), although there was a planned schedule. The interview questions followed three main themes: (1) support from the InnoPlay project, (2) conducting TE with young learners, and (3) the in-service training of teachers of TE to young learners. The video data of the recorded interviews consisted of a total of eight hours of material. The interviews were hosted either on site or online.

Table 1 Background of the teachers of young learners

Teachers of young learners (N=12)	Education	Working as	Working experience in years (educational level)
<i>School 1 (S1)</i>			
Yasmin	MEd	Class teacher	25 (basic)
Yvonne	MEd	Class teacher	22 (basic)
Yasir	MPhil (physics)	Principal*	30 (upper secondary and basic)
<i>School 2 (S2)</i>			
Katherine	BA (ECEC)	Pre-primary teacher	29 (pre-primary)
<i>ECEC centre 1 (EC1)</i>			
Kimberly	BA (ECEC)	Head of ECEC centre	13 (ECEC and pre-primary)
Kodi	BA (ECEC)	Digitutor**	23 (ECEC and pre-primary)
<i>ECEC centre 2 (EC2)</i>			
Nellie	BA (ECEC)	Pre-primary teacher	25 (ECEC and pre-primary)
Noelle	BA (ECEC)	Pre-primary teacher	11 (ECEC and pre-primary)
<i>ECEC centre 3 (EC3)</i>			
Vicky	Master of Social Services	Head of ECEC centre	20 (ECEC and pre-primary)
Veronica	Bachelor of Social Services	Pre-primary teacher	15 (ECEC and pre-primary)***
<i>ECEC centre 4 (EC4)</i>			
Crystal	BA (ECEC)	Head of ECEC centre	12 (ECEC and pre-primary)
Curtis	Vocational Qualification in Education and Guidance	Pre-primary teacher****	30 (ECEC and pre-primary)

*Subject teacher in physics. Working also as a head of local education and culture department. **Working as a digital skills teacher in pre-primary education. ***Which of 12 years in child welfare. Has also role as digitutor. ****Working as a substitute teacher

The interviews were transcribed before analysis, and the transcribed videos were analysed using qualitative content analysis (Krippendorff, 2019). The adapted MAP model (Fig. 1) formed the coding manual for the theory-based analysis. The units of analysis were the phrases the teachers used when reflecting on their experiences during the interviews. In total, 823 units of analysis were categorised into various subcategories of teachers' competencies according to the coding manual, using the NVivo 12 software. From these units, only the individual competency categories related to knowledge base and personal orientations ($n=365$) units selected for inclusion in this study (Table 2). To ensure consistent interpretations, the whole analysis was conducted by two researchers working at the InnoPlay project. This allowed discussions related to interpretation to occur throughout the categorisation analysis. After the analysis, the relevant material was read through by each subcategory. Few changes were made between the subcategories.

Results

The qualitative theory-based content analysis (Table 2), which used the MAP model, revealed that the teachers frequently referred to the individual competencies of knowledge base ($n=233$) and personal orientations ($n=132$) when describing their experiences of providing TE to young learners'.

Knowledge base

Content knowledge

The analysis units related to the content knowledge category ($n=47$) mostly referred to teachers' individual knowledge of the subject. The teachers' experiences indicated that an

Table 2 Units of analysis in knowledge base and personal orientations

Individual competencies	Units of analysis ($n=365$)
Knowledge base	233
Content knowledge	47
Pedagogical knowledge	42
Pedagogical content knowledge	87
Practical knowledge	36
Contextual knowledge*	6
Personal orientations	132
Personal dispositions	43
General patterns of adaptation	28
Professional identity	50

*Was emphasized only in five of the six organizations. Bold font is used to identify the sub-domains of "Knowledge base" and "Personal orientations" as reflective of the adopted theoretical framework.

Bold values indicates sub-headings/sub-domains of Knowledge base and Personal orientations

individual content knowledge of technology was a key competence. When the technological issues were more complex, the teachers highlighted the importance of understanding the content more deeply. For example, they reflected on the necessity of gaining the knowledge of how to use different devices before teaching them to young learners:

‘Well, it’s just how Veronica said, that you need to manage the device before you can teach it. Unless it [the teaching] won’t work’ (Vicky, EC3).

The teachers reflected on their fear or uncertainty about teaching technological content. For example, unfamiliar content such as that related to light-emitting diode (LED) lights or using digital devices in teaching caused them to distrust their individual teaching ability. The teachers’ content knowledge was also found to be superficial in some cases; for example, content-specific language, such as the exact terms for certain technologies, was missing. The teachers were sometimes unable to find the correct terminology and bypassed it with mentions such as, ‘I can’t remember the technique, something with paper and paste [papier mâché]’ (Vicky, EC3) and ‘electricity stuff [circuit]’ (Katherine, S2). When reflecting on the skills needed in TE projects, the teachers used vague parlance such as, ‘all sorts of measuring and investigating’ (Kodi, EC1).

Pedagogical knowledge

In the pedagogical knowledge category (n=42), the teachers emphasised two key competences: valuing child-centred teaching, and the ability to integrate different subjects, themes, or skills when teaching technology. The teachers highlighted, for example, the ‘participation of young learners’ (Kodi, EC1; Vicky, EC3), ‘young learners’ own ideas’ (Katherine, S2), and ‘doing inspiring and interesting projects with young learners’ (Kodi, EC1; Crystal, EC4). Child-centeredness was particularly emphasised when the teachers reflected on the facilities they used for TE projects. For example, when discussing the teaching group size for young learners’ TE projects, child-centeredness was a starting point for one teacher:

‘Well, the group size. It [the TE project] must be done in small groups. Then, we can get every child’s voice audible, and the children have an impact on [the project]. We had a quite ideal [teaching] group size of 11–13 children’ (Kodi, EC1).

The teachers also highlighted the project-based approach taken during their experiences. Integrating different themes, subjects, and skills within the projects was found to be relevant. The teachers mentioned integrating ‘maths and literacy’ (Nellie, EC2), ‘drama’ (Kodi, EC1), and skills for managing daily life, such as ‘perseverance’ (Yvonne, S1), within their TE projects. Especially in pre-primary settings, teaching was seen as a holistic project in which different content, including technology, is integrated on a daily basis. This project-based approach also promoted child-centeredness. For example, one teacher reflected that ‘children are more engaged in the longer projects’ (Katherine, S2).

PCK

The PCK category was emphasised in 87 units of analysis. According to the teachers’ descriptions of their experiences, the fundamental element of PCK was to find a meaning, direction, or orientation for the content to be taught. The teachers demonstrated the importance of the ‘pedagogical leading thought’, meaning that every action had a reason. One

teacher highlighted the pedagogical process using the example of learning in the woods with young learners:

'It's not only that we go to the woods. It's what we do there. We do many things there: we learn language, mathematics, science, and technology. It's about what children find from the woods and what they experience there' (Crystal, EC4).

The concept of the 'pedagogical leading thought' encompassed various content and themes described by the teachers. They integrated both larger content areas and more detailed and targeted skills to be learned. The larger content included, for example, 'learning language, mathematics, science, physical exercise, and arts' (Kodi, EC1; Vicky, EC3; Crystal, EC4). The more detailed skills included 'learning colours during physical exercise' (Vicky, EC3), developing 'thinking skills' (Kodi, EC1; Veronica, EC3), and 'practicing emotional skills' (Nellie, EC2). One teacher described working with TE projects as a process of teaching thinking and understanding:

'I see working with projects [as] I teach children to understand things, and with that they can create something new' (Kodi, EC1).

The direction of learning in the teachers' TE projects targeted their pedagogical underpinnings to the specific themes tied to the curricular content, such as learning 'language and reading' (Vicky & Veronica, EC3), 'culture' (Crystal EC4), 'sound and music' (Nellie, EC2), and 'coding' (Curtis, EC4). The TE projects were also based on 'story books' (Veronica, EC3), 'important dates (e.g., Christmas, Mother's Day, and Kalevala Day to celebrate Finnish culture)' (Crystal & Curtis, EC4), 'investigating how sound works and making their own instruments' (Nellie, EC2), and 'integrating coding and embroidery' (Curtis, EC4).

The teachers also reflected on their experiences of 'joining the content close to the children's daily life' (Katherine, S2; Vicky & Veronica, EC3). In other words, themes from the real world were included in young learners' learning and play. For example, 'mathematics was integrated into hospital play' (Katherine, S2) and 'coding to putting toys away to their own places' (Vicky, EC3). Teachers' pedagogical decisions for themes and content were unanimously identified as being 'child-centred' (Katherine, S2; Kodi, EC1; Nellie, EC2; Vicky & Veronica, EC3). The teachers took into account young learners' interests and strengths and incorporated them into the planning process of the projects. For example, the young learners were 'interested in animals that live in the Finnish forest, so we built the [TE] project around that theme' (Katherine, S2).

Practical knowledge and contextual knowledge

Practical knowledge was emphasised in 36 units of analysis, while contextual knowledge appeared in only 6 units. The teachers reflected on the practical arrangement of TE projects. The main practical feature mentioned was time management within projects. For example, one teacher described dedicating time and planning the teaching so that the technology projects were effective:

'It's important that the adult is really attentive to the process and not doing other tasks at the same time—in all activities, but especially in the teaching of technology. You have to dedicate a sufficient amount of time to these projects because the actions are long term' (Vicky, EC3).

From a practical perspective, the teachers indicated that they planned their teaching so that some of the young learners were doing technology projects while others were doing other activities. One teacher described how she planned to do a movie project with programmable robots; the key was that ‘the project was integrated to the normal school day and only couple of young learners at a time were doing the movie project with the adult’ (Katherine, S2).

The interviewed teachers were divided in their beliefs about the ideal group size for young learners doing TE projects. Some felt that size of a pre-primary education teaching group (i.e., 11–14 young learners) was suitable (Kodi, EC1; Crystal & Curtis, EC4) while others felt that the optimal group size for TE projects was less than 5 young learners (Yasmin & Yvonne, S1; Katherine, S2; Vicky & Veronica, EC3). In addition, two of the teachers—although they did not designate a specific suitable group size—speculated that ‘too large group will not work’ (Nellie & Noelle, EC2). The teachers also emphasised that the learners’ age, the learners’ individual support needs, and the activities being done all influenced the ideal group size. From a contextual perspective, the teachers communicated that the fact that pre-primary education only occurs for one year was problematic for conducting TE projects. For example, one teacher noted that ‘clients, the young learners, and also personnel changing every year makes the planning of long-term projects difficult’ (Kodi, EC1).

Personal orientations

Personal dispositions

The teachers were recognised reflecting on their personal dispositions towards teaching technology in 43 analysis units. They emphasised their individual strengths and motivations, and their propensity to stay within their comfort zone with the content. For example, when asked to describe the differences in their experiences of teaching traditional craft projects and technology projects, and to identify the most difficult aspects of the projects, they referred to inconveniences:

‘For me, the craft project is easier’ (Noelle, EC2);

‘Maybe the most difficult thing is starting the project’ (Nellie, EC2).

One teacher also had a strong personal disposition related to the effect of her background on her lack of familiarity with technology. She explained how her parents had raised her to avoid technology, such as ‘warning of the dangers of electricity and not even letting her change a lightbulb by herself’ (Katherine, S2). The teachers’ descriptions of their experiences showed that their individual interests and motivations did affect their provision of TE. They highlighted that they enjoyed ‘studying unfamiliar content first by themselves to teach them forward’ (Veronica, EC3) and ‘the joy of learning a new and huge interest in STEAM’ (Kodi, EC1).

General patterns of adaptation

General patterns of adaptation were emphasised in 28 units of analysis. The teachers’ experiences often related to their self-efficacy in teaching technology, their professional beliefs and preconceptions about technology, and their motives and interests related to TE. The teachers described their own courage in trying out different TE

projects (Nellie, EC2; Yasir, S1), and one teacher highlighted the importance of facilitating positive experiences of TE and of devices working as they should 'to spark the whole school to try technology projects' (Yasir, S1).

Professional beliefs were referenced mostly in relation to the teachers' differing experiences with teaching traditional crafts and TE projects. Crafts were considered 'conventional, especially for the older teachers' (Katherine, S2; Kimberly, EC1), while technology was considered something that they 'needed to learn during their working life' (Katherine, S2). The teachers also indicated that their pedagogical preconceptions, such as their belief in the joy of learning, were fundamental aspects of teaching young learners:

'But I think for us in ECEC that [the joy of learning] is the important thing. That is my opinion' (Kodi, EC1).

Such pedagogical intuition was also emphasised in teachers' motives and interests in teaching TE projects. They particularly noted the value of young learners' participation. The implementation of TE was viewed by the teachers as important and challenging, with teacher-directed teaching being criticised because 'young learners copy a model from the teacher's ideas' (Katherine, S2; Vicky, EC3) and because 'the idea does not come from the young learner' (Katherine, S2; Veronica, EC3). One teacher also described the challenge of trying to 'figure out how young learners could participate in the projects' (Kimberly, EC1).

Professional identity

The concept of professional identity appeared in 50 units of analysis, with the teachers describing their identity as TE teachers as forming a comprehensive process in which child-centeredness, inspiration, initiative, and commitment to work interconnect. Incorporating TE projects into their teaching was a meaningful experience to the teachers and became a source of their own professional identity:

'It [teaching technology] is not so difficult. It can be carried out with children easier than I thought. I realised that my perception has changed—that I don't need to be an ICT engineer to do these projects with children' (Veronica, EC3).

The teachers' experiences also revealed that dealing with broader entities and integrating different content was meaningful to their professional identity as a provider of TE. For example, they highlighted the integration of 'design thinking and different technological content, such as basic coding' (Veronica, EC3) and the teaching skill of 'taking into account each child's world and ideas comprehensively' (Kodi, EC1).

The teachers' ability to take initiative and recognise the importance of professional development were also highlighted in their experiences. Many planned to participate, or were already participating, in in-service training on various topics—such as 'positive pedagogy and well-being' (Kodi, EC3), 'STEAM' (Katherine, S2), 'robotics' (Veronica, EC3), and, more generally, 'new innovative stuff that could be done with children' (Crystal, EC4)—to enhance their individual skills. Two of the teachers also reflected on their commitment to their work as educators and their responsibility to conduct TE projects in the future (Veronica, EC3; Kodi, EC1).

Discussion and limitations

This study investigated teachers' individual competencies in teaching TE projects to young learners. The teaching profession is constantly evolving, but this evolution can be difficult to see; therefore, it can be difficult to conduct analyses of teaching practices in real time (Shulman, 1987). This study used one of the many frameworks of teacher competence, the MAP model, in which teachers' individual and teaching competencies are divided into sub-domains and seen as fundamental aspects relating to effective performance in the teaching profession (Metsäpelto et al., 2020, 2021). The MAP model was created through a broad theoretical investigation of earlier research, and its foundations lay in Blömeke et al.'s (2015) framework of competence as a continuum. For a targeted purpose, such as assessing teachers' individual experiences in providing TE to young learners, the MAP model may be too multidimensional. Therefore, this study used only part of the model, focusing on the individual competencies required for the provision of TE to young learners. The general teaching competencies necessary among the teachers of young learners will be investigated in another study as part of a larger project.

This novel approach involving the use of the MAP model in the analysis gives both theoretical and methodological possibilities and limitations. The MAP model, with its many domains and sub-domains, is an intertwined entity. For example, individual competencies, such as PCK, involve plans and strategies for teaching (Shulman, 1987) that are also recognised as relevant teaching competencies. Therefore, the analysis of this study was conducted entirely by two researchers, to ensure consensus regarding interpretations. Hence, because of the slight differences between the sub-domains, there is a possibility that interpretations could have made differently. For example, in relation to pedagogical knowledge, the teachers were reflecting on teaching as a whole (i.e., not specifically focusing on TE projects), while in relation to PCK, the teachers were reflecting on teaching technology or technological content. The MAP model recognises teachers' personal orientations, which sets it apart from, for example, the widely used TPACK model (Mishra & Koehler, 2006). In the context of young learners' TE, in which teachers' personal orientations are relevant (Hatzigianni et al., 2024; Havice et al., 2018), the examination of individual competencies without personal orientations would have been deficient.

Priestley et al. (2016) showed that teachers' backgrounds, including both their professional and personal histories, are an important source in the development of their educational vision. In addition, their competencies, especially PCK, are related to their teaching experiences (Doyle et al., 2019b). The teachers participating in the current study have worked with young learners for many years. Although the small sample size in this study limits the generalisability of the results, the teachers' reflections indicated that only after participating in small-scale in-service training and conducting TE projects with young learners were they able to realise the meaning and importance of technology. Similar findings related to the outcomes of positive attitudes and beliefs towards technology integration in young learners' TE have been reported in earlier research (Lim et al., 2024; Mejovaara et al., 2024; Mertala, 2019).

In this study, the teachers seemed to understand the nature of technology—that it occurs everywhere in young learners' surroundings and that technological literacy is increasingly necessary. Accordingly, emphasising technological literacy in teacher education could benefit the TE and technological literacy of young learners. As Frederik et al. (2011), stated that technological literacy is the aim of the teaching technology. However, for implementation of technological literacy, higher-order thinking should be triggered in the TE of young

learners. Triggering higher-order thinking has also been cited as important in our earlier research in teacher–young learner interactions in coding and robotics (Korkeaniemi et al., 2023). We therefore suggest that future research should focus more on teachers' abilities and competencies in triggering young learners' higher-order thinking skills. For that, in-service training related particularly to the PCK necessary for directing the TE of young learners should be investigated. Also, to tackle current technological issues and trends, such as artificial intelligence (AI), teachers' technological literacy and comprehension of the nature of AI should be studied. Results of this study could be applied as a framework for developing also AI practices for initial teacher education and in-service training of young learners' TE.

Theorists have long emphasised the importance of behavioural dynamics, social learning, and cognitive schemata over dispositional traits (McAdams & Pal, 2006). This paradigm shift to a more individual approach that focuses on teachers' dispositional orientations could be beneficial for young learners' TE. We suggest a 'bottom-to-top' approach for the in-service training of teachers, wherein technology is raised or added to teachers' pre-existing personal dispositions, interests, and motives. This approach could make the content more relevant and a more natural part of their profession. The ongoing development of technology forces teachers to equip themselves with skills to integrate technology into their teaching, and hands-on activities have been identified as an efficient means by which to accomplish this (Brown et al., 2016; Mahmud et al., 2018). These hands-on activities should be targeted in the in-service training context, with more experienced and TE-oriented teachers collaborating with teachers who are not so familiar with the content of technology. According to Klassen and Tze (2014), self-efficacy is influenced by the occurring context. As such, this mentoring from experienced teachers in a collaborative environment may benefit the self-efficacy of teachers providing TE. Such collaboration has been described in earlier research (Peretti et al., 2024; Wang et al., 2024). Past research has also indicated that teachers are struggling to locate their individual work within the broader purposes of education (Biesta et al., 2015). The current study has shown that teachers are able to connect TE to these broader educational purposes, such as young learners' ability to collaborate and work together. Socialising young learners (Biesta et al., 2015) and the project-based approach to TE (Bers et al., 2019; Korkeaniemi et al., 2023) contribute to the long-term aim of cultivating collaboration skills that students will require in educational and societal settings in the future.

Conclusion

The aim of this research was to identify the individual competencies recognised by teachers as being necessary in their experiences of providing TE to young learners. Based on the results of the study, eight key individual competencies were found to be vital in providing TE projects to young learners. The key individual competencies are presented in the framework shown in Fig. 3.

The framework of the key individual competencies of teachers in the provision of TE projects to young learners intertwines two domains, each with four sub-domains. The knowledge base domain includes the following four sub-domains:

- Content-specific knowledge: The teacher's individual understanding of the content before teaching it to young learners

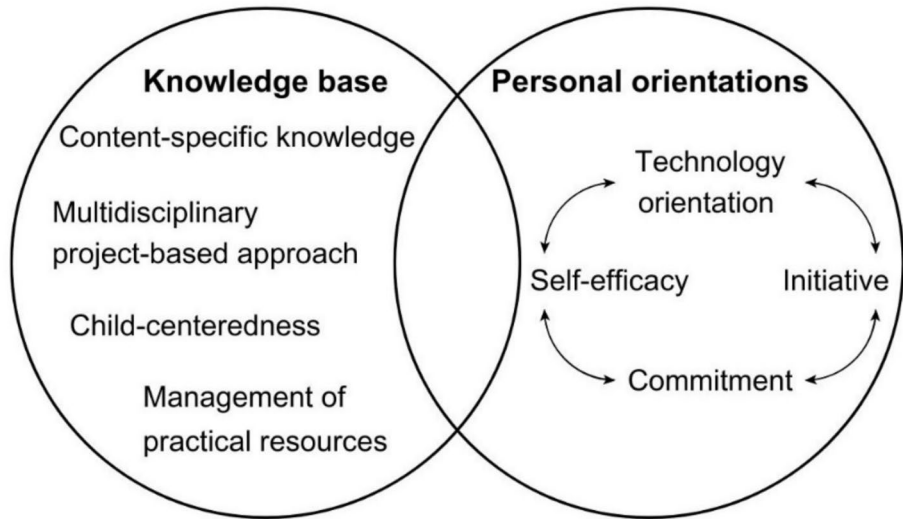


Fig. 3 Framework of key individual competencies of teachers in the provision of TE to young learners

- **Multidisciplinary project-based approach:** The teacher's integration of different STEAM concepts and skills for managing daily life into TE projects
- **Child-centeredness:** The teacher's pedagogical intuition to follow young learners' ideas, to connect teaching to their everyday life, and to emphasise their participation
- **Management of practical resources:** The time the teacher spends on planning and conducting projects, and arranging teaching to small groups

The personal orientations domain includes the following four sub-domains:

- **Technology orientation:** The teacher's motivation, interest in technology, and aspiration to understand and teach technological content
- **Self-efficacy:** The teacher's courage to plan and conduct projects, and their willingness to get out of their comfort zone
- **Commitment:** The teacher's ability to commit to projects and to understand the teaching profession as an ongoing process of learning new skills
- **Initiative:** The teacher's tendency to create new projects and develop their individual skills

There are many different models of teachers' competence, such as Guerriero and Révai's conceptual framework (2017), Blömeke et al.'s (2015) competence as a continuum, Leijen et al.'s (2020) model of the formation of agency, the ecologically situated model of enacted practice in teachers' beliefs and knowledge (Doyle et al., 2019a), and the TPACK framework (Mishra & Koehler, 2006). This study highlighted the MAP model (Metsäpelto et al., 2020, 2021), using it to build a framework (Fig. 3) to create new knowledge for developing teachers' key individual competencies to enhance the TE of young learners and to develop the in-service training of teachers in TE. The implementation of the identified key individual competencies may be extended to include not only teachers involved in the provision of TE to young learners but also those

working on various participatory and child-centred projects in young learners' educational settings.

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article. The manuscript is approved by all authors for publication. On behalf of my co-authors, I declare that the work described is original research that has not been published previously, and not under consideration for publication elsewhere.

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