AUTHOR	Marja-Leena Rönkkö, Virpi Yliverronen, Kaiju Kangas
TITLE	Investigative activity in pre-primary technology education—The Power Creatures project
YEAR	2021
JOURNAL	Design and technology education: an international journal
VERSION	Author's accepted manuscript
CITATION	Rönkkö, M., Yliverronen, V., & Kangas, K. (2021). Investigative activity in pre-primary technology education: The Power Creatures project. Design And Technology Education: An International Journal, 26(1), 29-44. Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/2885

Investigative activity in pre-primary technology education—The Power Creatures project

Marja-Leena Rönkkö, University of Turku, Finland
Virpi Yliverronen, University of Turku, Finland
Kaiju Kangas, University of Helsinki, Finland

Abstract

The present study explored pre-primary students' investigative activity during a longitudinal, integrative technology education project: the Power Creatures project. Investigative activity refers to the way young children act in a learning context that combines inquiry-based activities with creative hands-on activities, such as designing and crafting. Nineteen pre-primary students (aged five to six years) and two teachers participated in the case study. The main data set consisted of six video-recorded small-group sessions in which the children experimented with electronics and designed and made felted creatures containing soft circuits. The data were analysed using a theory-based, deductive content analysis. The results indicate that playful, investigative activities support pre-primary students' learning of everyday technologies and that children can transfer their understanding of the technological process from one situation to another. This process requires careful pedagogical planning and scaffolding that maintains the longitudinal process and adapts to its established and evolving goals.

Keywords

pre-primary education, technology education, investigative activity, STEAM, craft education, child-centred pedagogy

Introduction

Starting from a very young age, technology plays a significant role in children's lives. Therefore, in recent years, technology education has been emphasised as important in the early years of education curricula (Fleer, 2011; Marsh, 2016; Sundqvist & Nilsson, 2018). Early childhood is a period in which the foundation for effective and enduring learning is built (Mawson, 2010; Turja, Endepohls-Ulpe & Chatoney, 2009). The purpose of technology education is to help children understand everyday technology and how it can be used to solve daily life problems (Fox-Turnbull, 2019; Sundqvist & Nilsson, 2018). Here, children are encouraged to observe a technological environment in which they learn to compare, classify and organise the information acquired through observations or measurements, hence supporting their growth as thinkers and learners. At the essence of young children's technology education is emphasising human activity, innovative solutions, and inquiry-based and experimental activities, not technical devices (FNBE, 2016; Kilbrink, Bjurulf, Blomberg, Heidkamp & Hollsten, 2014). Learning goals should have significant overlaps with scientific, engineering and design practices, as well as crosscutting concepts (Quinn & Bell, 2013).

In the present research, we situate pre-primary technology education within the integrative STEAM (science, technology, engineering, arts, and mathematics) approach (e.g., Bequette & Bequette, 2012). In STEAM, the 'A' refers to not only arts but also design and humanities (Daugherty, 2013), shifting the focus from technology as applied science towards more multidisciplinary and creative problem solving (Jones, Buntting & de Vries, 2013; Williams, 2012). This shift has been fuelled by the need to educate—starting from early stages of education—future citizens who can understand, critically reflect and creatively influence the technological world (Ge, Ifenthaler & Spector, 2015). The integrative and future-oriented approach to technology education is also emphasised in the Finnish National Core Curriculum for pre-primary education (FNBE, 2016). The curriculum highlights encouraging children's interest in science and technology, creative designing and making, problem solving, examining and experimenting with structures and materials, and reflection on the processes and products. According to the curriculum, all competences are approached and learned in integrative ways.

We present a longitudinal STEAM project, the Power Creatures project, where pre-primary students explored electricity as a phenomenon and designed and constructed felted toys containing soft circuits (Yliverronen, Rönkkö, & Kangas, in press). The main aims of the project were to familiarise children with everyday technologies, especially electronics, to practice inquiry-based and creative hands-on activities and to support children's self-confidence and self-esteem. Following the guidelines of the curriculum (FNBE, 2016), the project emphasised child-centred pedagogy and playful elements, along with various technology-related, hands-on activities. In child-centred practices, children are viewed as active knowledge constructors, and the adult's main role is mainly to facilitate this by providing guidance, opportunities and encouragement (Cremin, Glauert, Craft, Compton, & Stylianidou, 2015; Lerkkanen et al., 2016). In the project, hands-on activities involving designing were seen as powerful vehicles for teaching STEAM content (see Lindeman, Jabot & Berkley, 2014; Park, Byun, Sim, Han, & Baek, 2016) because these activities encourage experiential learning, especially when learning is integrated and not too subject oriented (Bennett & Monahan, 2013; Honey & Karter, 2013). Furthermore, the STEAM approach was seen as an effective way to teach young students creative technological competencies (Ghanbari, 2015; Lindeman et al., 2014).

In the present study, we use the term *investigative activity* to describe the way young children act in the context of working on a project involving both inquiry-based and creative hands-on activities (Yliverronen, Marjanen & Seitamaa-Hakkarainen, 2018). Investigative activity refers to a process in which young children craft, design, apply technology and learn science, integrating several objectives of early years education in a child-centred way. Our aim is to examine how pre-primary students' learning of everyday technologies can be supported with investigative activities. We addressed the following research questions:

1. What is the nature of pre-primary students' investigative activities in a STEAM project focusing on everyday technologies?
2. What types of pedagogical practices support pre-primary students' investigative activities during a longitudinal STEAM project?

The current paper is organised as follows: First, we will discuss inquiry-based and creative activities in pre-primary education and present Stylianidou et al.'s (2018) theoretical framework that summarised the pedagogical synergies found in both approaches. Then, we will consider the role of hands-on design and craft activities in early years technology education. In the methods section, we will explain how we adapted the framework for exploring pre-primary students' investigative activities. Finally, we will present the findings and conclusions.

Inquiry-based and creative hands-on activities as vehicles for STEAM learning

Pre-primary education is an important period in children's lives, offering them opportunities to be inspired by various fields, to experiment and to learn new things. When learning activities are connected to children's experiences, they have the opportunities to imagine, explore, experiment, ponder and recognise various phenomena. Research on early years education highlights the affective dimension, such as being imaginative and innovative and creating the possibility for question-posing, self-determination (e.g., Craft, McConnon & Matthews, 2012) and playful experiences (e.g., Larsson & Halldén, 2010) as necessary conditions for learning because they nurture children's motivation to understand the world. Fascination and wonder can trigger engagement and curiosity, leading to the use of inquiry practices to develop explanations for phenomena (Milne, 2010). By engaging in inquiry (i.e., the processes of observing, questioning, predicting and evaluating), young children learn how to construct knowledge, particularly when guided and encouraged by adults (Hollingsworth & Vandermaas-Peeler, 2017).

Combining inquiry-based learning with creative activities in early childhood education has been emphasised in several studies, especially in relation to science education. Through an extensive review of policy-related and research-based literature, Stylianidou et al. (2018) created a conceptual framework of eight common pedagogical synergies that run between inquiry-based and creative approaches in early years science education: 1) play and exploration, 2) motivation and affect, 3) dialogue and collaboration, 4) problem solving and agency, 5) questioning and curiosity, 6) reflection and reasoning, 7) teacher scaffolding and involvement and 8) assessment for learning. These synergies highlight that both inquiry-based and creative approaches can be employed as tools for developing knowledge creation and learning, and both offer motivational support for promoting positive attitudes about science and creative ways of working (Stylianidou et al., 2018). Moreover, children's exploratory and investigative engagement have been both recognised as being important for furthering young students' creativity and science education and their consideration of ideas and concepts (Cremin et al., 2015).

The first pedagogical synergy, *playful exploration*, is inherent in all young children's activities (Stylianidou et al., 2018). Activities with inventive and experimental elements allow children to act in a way that is natural for their age: learning by exploring, doing and playing. Pre-primary technology education needs the space for imaginative play and playful elements along with more goal-oriented activities (Yliverronen et al., 2018). Research, interpretation and imagination together develop children's competencies broadly: play is a key element in young children's learning processes (FNBE, 2016; Lindqvist, 2003; Vygotsky, 1978). Furthermore, narratives have been shown to engage children's imaginations and foster their creativity (Cremin et al., 2015). *Motivation and affect* underline the role of aesthetic engagement in promoting children's affective and emotional responses to various learning activities (e.g., Craft et al., 2012). *Dialogue and collaboration* support learning in many ways, such as fostering a deep understanding (e.g., Sawyer, 2006). They enable young children to externalise, share and develop their thinking and verbal reasoning skills (e.g., Alexander, 2020; Fox-Turnbull, 2019; Mercer & Littleton, 2007). Discussion and the sharing of ideas and ways of thinking develop increased awareness, which can improve one's own ideas (Cremin et al., 2015).

Problem solving and agency, as well as *questioning and curiosity,* are at the core of inquiry-based and creative activities; the emphasis on children's own questions and investigations is fundamental. Open-ended investigations do not have a predetermined outcome: unrestricted starting points lead to a variety of solutions and support children's creativity (Driscoll, Lambirth & Roden, 2015). Chappel, Craft, Burnard & Cremin (2008) argued that creative teachers often employ open-ended questions and promote speculation by modelling their own curiosity. However, if young children have little experience with open questions, they may find them difficult (Harris & Williams, 2007). In addition to discussions, children's curiosity and questions may be expressed through drawings, gestures, working with materials and play (Wood & Hall, 2011). Research (e.g., Craft et al., 2012; Cremin et al., 2015) has shown that young children's engagement in identifying their own problems is central to creativity, and teachers' interest in and respect for children's questions facilitate the children's sense of autonomy and agency as learners. Engagement with problems fosters a child's ownership of learning, decision making and self-determination. Through a scaffolded learning environment, children can be provided with shared and meaningful experiences and develop their creativity, as well as formulate questions and ideas about relevant concepts.

The activities of *reflection and reasoning* underline the importance of metacognitive processes, reflective awareness and deliberate control of cognitive activities (Stylianidou et al., 2018). In early years education, these abilities are still developing, and teachers' sensitivity to children's needs plays a central role in working with young learners (Fleer, 2000). Teacher *scaffolding and involvement* often occurs in practical situations, but it also occurs when a teacher scaffolds children's thinking between everyday experiences and more formal scientific concepts. This process involves teaching thinking skills, which help foster children's independence as problem solvers (Bodrova & Leong, 2012). The last pedagogical synergy in Stylianidou et al.'s (2018) conceptual framework is *assessment,* which refers to the formative assessments of children's skills, attitudes, knowledge and understandings.

In the present study, we employ Stylianidou et al.'s (2018) framework in the context of STEAM-based technology education, where inquiry-based activities were combined with creative hands-on activities. Young children's technology education should be a place that fosters children's imagination and playfulness (Fleer, 2000). Children have an inner capacity to imagine, invent and create, giving them the potential to learn many ideas from concrete hands-on experiences (Turja et al., 2009). Integrating technology education with hands-on design and craft education is a logical approach because these learning areas have common objectives and procedures: children are encouraged to discover, construct projects out of various materials and resolve and describe the technological problems they have encountered (Yliverronen et al., 2018). The implementation of hands-on activities requires learners to practice multiple competencies, such as participation, collaborative problem solving, investigation, explanations and arguments that are personally relevant and related to their lives. Through design and hands-on activities, learners can identify a problem or need, solve various subproblems, consider various options for a design and test and implement their own ideas (Fox-Turnbull, 2019). Design-based activities can be inherently motivating for children because most children are interested in making things, and through design, they have the opportunity to engage in independent decision making concerning their own work (Bennett & Monahan, 2013).

Method

The present qualitative case study took place in a public kindergarten's pre-primary group in a western Finland urban area during the 2019 autumn term from September to December; the project comprised 20 sessions over a period of four months. A total of 19 pre-primary students (9 girls and 10 boys) who were aged five to six years and two teachers participated in the longitudinal Power Creatures project. During the working sessions, the whole group was divided into groups of six or seven children to ensure a safe work environment and sufficient adult support.

The empirical data consisted of six video-recorded small-group sessions, including children's hands-on activities and experimentation with electronics. These six sessions were selected to give an accurate description of the children's and teachers' activities at various stages of the project. This amount of data enabled us to conduct an analysis that was fine-grained enough to reveal detailed activities without losing the overall view of the project. The video recordings were made in two learning spaces as the children progressed in the project at varying paces. The rich and dense data were obtained with GoPro cameras attached to the children's heads. As additional data, field documentation (notes and photos) collected by the project assistant and researcher, as well as children's sketches and finished Power Creatures, were used. The same data were analysed in our previous study (Yliverronen et al., in press), in which we examined the implementation of the project and the teachers' supporting activities on a general level.

Table 1. The framework for analysing the Power Creatures project (adapted from Stylianidou et al., 2018)

RQ1. The nature of children's investigative activities	**Inquiry-based and creative approaches**	**RQ2. The types of supporting pedagogical practices**
Inquiry-based and creative hands-on activities	Play and exploration	Teacher scaffolding and involvement
	Motivation and affect	
	Dialogue and collaboration	
	Problem solving and agency	
	Questioning and curiosity	
	Reflection, reasoning and assessment	

In the present study, we analysed the data using a theory-based, deductive content analysis method (see Elo & Kyngäs, 2008). For the analysis, we adapted Stylianidou et al.'s (2018) framework of the common pedagogical synergies between inquiry-based and creative approaches in early years science education, identifying a) the children's investigative activities and b) the supporting pedagogical practices within each theme of the framework (see Table 1). Stylianidou et al.'s (2018) themes *reflection and reasoning* and *assessment for learning* were combined because during hands-on activities, the constant interaction of thinking and doing is pivotal (see Kimbell, 1994), and the evaluation of the process, instead of the end result, is underlined. The theory-based framework helped us conceptualise the empirical data and understand how pre-primary students' learning of everyday technologies could be supported with investigative activities.

Findings

Overview of the Power Creatures project

The aim of the present study was to analyse the nature of children's investigative activities and their pedagogical support during the integrative Power Creatures project, which focused on everyday technologies. The project phases and the teachers' and children's activities are presented in Table 2 within the framework of inquiry-based and creative approaches.

The Power Creatures project consisted of six phases, together forming a holistic process. The process involved exploring one's own strengths, an inquiry-based, playful orientation and studying of electricity, designing and making Power Creatures with soft circuits and evaluation of the whole process. The project included various investigative activities, which were supported by the teachers' scaffolding, as well as with the involvement of parents, grandparents and older students. In the following, we present more detailed findings, first regarding the children's investigative activities and, second, regarding the supporting pedagogical practices.

Table 2. The Power Creatures project phases and the teacher's and children's activities within the framework of inquiry-based and creative approaches

Project phase (total of 20 lessons)	**Teacher scaffolding and involvement**	**Children's investigative activities**	**Inquiry-based and creative approaches**
Exploring one's own strengths September (3 lessons)	Evoking children's interest and motivation, hearing their thoughts	- Discussing the themes of self-esteem and self-confidence - Finding their own strengths - Making a power poster	**Motivation and affect**
Orientation to electricity October (2 lessons)	Arousing curiosity and guiding thinking with relevant questions, discussions, and tasks	- Wondering about electricity as a phenomenon -Performing experiments from a children's electricity book	**Questioning and curiosity**
Studying circuits November (2 lessons)	Enabling playful exploration and child-centred activities related to circuits and conductive materials	- Playing an embodied 'Circuit play' - Testing different conductive or nonconductive materials	**Play and exploration**
Designing the Power Creatures November (5 lessons)	Supporting engagement, imagination and development of understanding with an open-ended design and making task	- Drawing the Power Creatures depicting their strengths - Making patterns - Designing the soft circuit and the placement of its components	**Problem solving and agency**
Making the Power Creatures November (5 lessons)	Enabling meaningful collaborative craft process with older students and parents	- Felting the basis of the Power Creature - Cutting the felt - Needle felting the details - Testing and sewing the soft circuits	**Dialogue and collaboration**
Evaluation of the process December (3 lessons)	Fostering awareness of one's own thinking and learning, encouraging self-reflection and reasoning	- Self- and peer-evaluation during the process - Telling stories about the creatures - Producing and staffing an exhibition of the Power Creatures	**Reflection, reasoning and assessment**

The nature of children's investigative activities

Because one of the goals of the project was to support children's self-confidence, the project began with activities related to this theme. The children's *motivation and affect* were evoked through an exploration of their own strengths—or their 'powers'. Children got to know 'Molli', a creature from a picture book by the Finnish author Katri Kirkkopelto. Molli is a small and angry character who lives alone in the middle of a big garden. Molli dreams of having a friend to share secrets, sit quietly together and play with. The teacher also read aloud Avril McDonald's picture book *The Wolf and the Shadow Monster*, which is designed to help children explore emotional intelligence and deal with confidence issues, such as managing anxiety and fears. The children discussed both of the books' themes with their teachers and played games related to them. Based on these activities, the children created their 'power posters', illustrating the strengths they considered to be important.

Another focal theme in the project was everyday technology, particularly electricity. Because the children did not know electricity as a phenomenon, their *curiosity and questioning* about the theme was evoked through wondering. Together with the teacher, the children pondered their everyday observations related to electricity and considered questions such as what would people do if there was no electricity. They also performed some tasks from *The Electricity Book of Little John*; this book was published by The Finnish Association for Electrical Safety and has several stories that reflect on the nature and development of technology with a playful approach. The idea is that children reflect on the stories and carry out the same tasks as Little John. At the same time, they learn about electrical safety. The book motivates children to explore everyday things, aiming to evoke their investigative attitude and own questions.
After these orienting activities, the children further studied electricity through *play and exploration* around the theme of circuits. At first, the children played a game called 'Circuit play', where they held each other's hands and tested how a message or impulse is transmitted. In the game, one child acted as a switch and sent an impulse. Another child was a buzzer, which rang when the impulse arrived. A third child acted like a battery, and the rest of the children were conducting bodies. This provided the children with the initial concept of a circuit, which helped them when the idea of this play was then transformed into a task with actual components—see Figures 1 and 2.

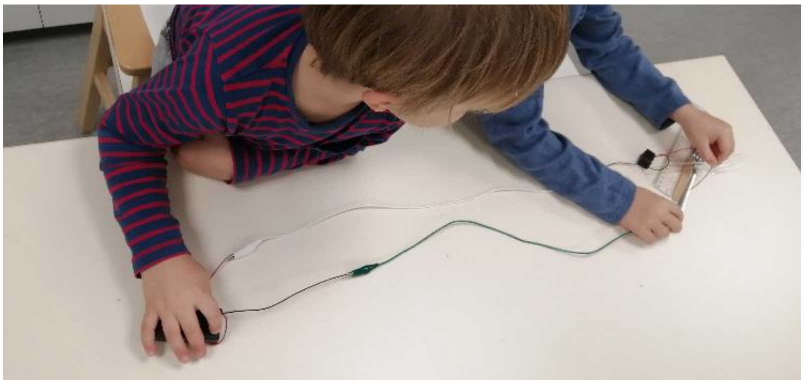

Figure 1. Children testing a circuit with forks

The children worked in pairs and constructed a circuit with alligator clips (resembling the holding of hands in the game 'Circuit play'), a battery and battery holder (like the child who acted as a battery), a buzzer (like the child who acted as a buzzer, making a sound indicating the arriving impulse) and any materials they could find in their surroundings. If a material conducted electricity, the buzzer rang. For example, a metal fork in the circuit made the buzzer ring, but a plastic box did not. The children expressed joy with excited whoops, exclaiming, 'It works!'

Figure 2. Children investigating whether the door handle conducts electricity

Children’s imagination can be supported by giving them open-ended tasks, which require creative *problem solving and agency*. Here, the task was to design and make a Power Creature, a felted toy with a soft circuit. The task integrated the previous phases of the project because the aim was to develop children’s emotional skills and self-esteem and support their understanding of electricity through creative design and craft activities. The children pondered their own character traits, shared their strengths with each other and designed a Power Creature by drawing. According to their drawings, the children also drew patterns to outline the shape of the soft toy and understand the amount of material needed for felting. In addition, they designed the soft circuits included in the creatures, as well as the placement of electrical components, such as LED lights for eyes or other details. Their understanding of the function of a circuit was clearly visible in these drawings, which can be seen as the first stage towards drawing a proper circuit diagram.

In the Power Creatures project, in addition to interacting with each other and with the teachers, the children also had *dialogue and collaboration* with their parents and older students. During the making phase, the children felted the wool pieces for their creatures. With a little help from their parents during a parents’ evening at the preschool, the children were able to make both the front and back pieces by using soap, warm water and abrasion. Together with Grade 4 school students (aged 9–10) who visited from a nearby school, the children felted some extra pieces for the creatures (Figure 3). After making additional pieces for both the front and back, the children cut the pieces according to their patterns and added details with needle felting.

Figure 3. Collaborative felting

In the next phase, Grade 8 students (aged 13–14) helped the children sew the soft circuits into the creatures using conductive thread, a coin battery holder and an LED light. Together, they first checked whether the circuit designed by the pre-primary student worked, and then, they sewed both pieces of the creature together. The finished Power Creatures were visible evidence of the children's knowledge created through embodied and materially mediated means; through them, both the children and adults were able to see what was accomplished during the project (Figure 4). The children were happy with their creatures and played with them eagerly.

Figure 4. Power Creature with a soft circuit that was tested and sewn in

Reflection, reasoning and assessment took place throughout the project, and several methods were used. The children reflected on their own actions through self-assessment, told stories about their creatures and gave feedback to each other. An assessment connected to crafting refers to the self-evaluation of the whole process, including the designing and making phases, as well as the ready-made product. As the 'grand finale' of the Power Creatures project, the teachers and children organised an exhibition of the creatures for parents, grandparents and older students. The aim was to provide the children with the opportunity to get feedback from relatives and older students and support them in reviewing the whole project through story crafting. However, the Power Creatures project, which lasted the entire semester and included 20 lessons in total, was challenging and demanding for the children and their teachers. In the end, the exhibition became an occasion to show the end results of the project, not an opportunity for reflection and reasoning focused on the process behind them. Story crafting was not implemented as planned because the children were too excited about the exhibition to focus on reviewing the months preceding it. Nevertheless, planning and organising the exhibition provided the children with opportunities to reflect on the project, even though this was not systematically utilised.

Pedagogical practices supporting children's investigative activities

Our second research question focused on the pedagogical practices that supported the children's investigative activities during the Power Creatures project. The longitudinal project included several dimensions and pedagogical choices as the children engaged in various investigative activities. Here, it was crucial to provide the children with timely scaffolding throughout the process. Aside from the teachers, parents, grandparents and older students were also involved in the project; however, only the teachers were responsible for meeting both the short- and long-term goals of the project. This required careful pedagogical planning both before and during the process, not only thinking in advance about the various steps of the project, but also responding to the moment-to-moment situations that arose in the classroom. All in all, very sensitive scaffolding and involvement was needed from the teachers to listen and employ the children's ideas and support the children's own thinking and acting. Carefully selected books, along with discussions and tasks based on them, were used to evoke children's *motivation and affect* towards the project themes. The teachers employed the pedagogical ideas in the books, such as guiding the children to draw a 'power poster' to support and develop their emotional skills and self-regulation.

The children's *curiosity and questions* about everyday technology were evoked with a discussion about electricity. The children did not know about electricity as a phenomenon, so their interest was aroused by asking questions about their everyday observations:

> *Let's imagine we don't have electricity now. What would we do? How would we survive at pre-primary school and at home? What things can you do to save on electricity consumption at school and at home? What concepts related to electricity do you know, and can you also explain their meaning?*

The teachers' questions and discussions, as well as the experiments from *The Electricity Book of Little John*, supported the children in thinking about electricity and how it affects their lives. Their thinking was further facilitated through *play and exploration*. The teachers organised playful explorations related to circuits and conductive materials, enabling the children to develop their understanding in fun and child-centred ways. The materially mediated and embodied activities enabled the children to investigate an invisible phenomenon—electricity—through tangible means. For young children, the use of one's own hands and body is the first step towards learning and is a prerequisite for using imagination to understand abstract concepts.

Designing and making the Power Creatures were the most time-consuming phases of the project; altogether, these parts lasted for 10 lessons, that is, half of the project's lessons. Hands-on activities with young children require time because of their still developing fine-motoric skills but also because meaningful hands-on work requires time for reflection. Children need time and support to understand the meaning of their activities in a way that enables their engagement and learning. In the Power Creatures project, the teachers facilitated children's *problem solving and agency* with a carefully planned design and making task. The open-ended task required the children to formulate their own subproblems—that is, how to design the creature so that it would reflect the strengths and other character traits they wanted. The teachers guided the children to draw creatures that depicted where they find strength in their everyday lives. They also supported the children's design by discussing previous activities in the project. The task was clearly motivating for the children because they empathised with the power figures, talked about their qualities eagerly and wanted to present their ideas to adults and other children.

During the making phase, in small groups, the teachers discussed and demonstrated several stages of the manufacturing process. For example, they pondered together about what the meaning of the pattern is, and the teachers reminded the children how scissors are used. Safety issues were highlighted especially in the needle felting phase; the teachers instructed the children to keep their fingers away from the sharp needle. The teachers also invited school students and parents to work with the children for two reasons. First, the aim was to guarantee enough hands-on support for the children, and the second aim was to enable cross-age *dialogue and collaboration* while making. On the one hand, the older students and parents were more competent in tasks requiring fine-motoric skills, but on the other hand, the children were experts regarding their own designs. This ensured both equal collaboration between the younger and older participants and a smooth progression of the making phase. Overall, the implementation of the design and making phases enabled several focused 'flow' experiences for the young children.

Throughout the project, the teachers fostered the children's awareness of their own thinking and learning, encouraging their *reflection, reasoning and assessment* of the process. They regularly offered the children the possibilities to practice self- and peer-evaluation, helping them articulate their thoughts. Besides verbal expression, the teachers considered children's embodied activities and tangible products (i.e., circuits, drawings, finished creatures) as important realisations of their thinking and learning. At the end of the project, the initial idea was to use story crafting for the teachers to get a final grasp of the children's understanding of the phenomenon of electricity. Although this was not carried out as planned, overall, the project highlighted several aspects related to young students' learning through investigative activities.

Conclusions

The aim of the present study was to explore how pre-primary students' learning of everyday technologies can be supported with investigative activities—that is, activities combining inquiry-based and creative hands-on activities. The conceptual framework of the synergies between inquiry-based and creative approaches by Stylianidou et al. (2018) supported the analysis, focusing our attention on children's activities and the pedagogical practices that foster both inquiry and creative hands-on activities. The analysis revealed that the synergies were present in the project, suggesting that the two approaches can be combined in pre-primary technology education. Furthermore, the results indicate that hands-on work with craft materials and tools can be successfully implemented in the learning process. The longitudinal STEAM project provided a groundwork for mixing various activities in a pedagogically meaningful way. This is the core of Finnish pre-primary education: to create learning modules in which diverse fields of knowledge are integrated to improve children's transversal competencies (FNBE, 2016).

Learning about everyday technologies—in this case the basics of electricity—took place through several iterative cycles of inquiry-based and creative, hands-on activities. The use of technological tools was first practised during the completion of simple tasks, and the newly learned competences were then adapted for creative purposes (Kilbrink et al., 2014). The simple tasks supported, for example, learning the names and functions of circuit components, but it was the holistic process with its diverse activities that provided the basis for understanding the meaning of the phenomenon. Milne and Edwards (2013) reported that five-year-old children were able to transfer their understanding of a technological process from one situation to another when they had sufficient language skills and background experience to support it. The more diverse the experiences the children have with technology, the easier it will be for them to learn new skills. The initial technological exploration that is associated with the creative process quickly turns into a structured activity when repeating the same type of identifiable activities (Harwood & Compton, 2017; Mawson, 2010). In the present study, the children were able to build their knowledge related to everyday technologies through various embodied and material experiments. Their understanding became visible to themselves and others through the design and making of the Power Creatures.

The results of the present study indicate that investigative activities support children's capacity to explore and understand electricity in their everyday lives. Furthermore, the findings show that teacher scaffolding and involvement throughout a project is crucial for its success and for the development of children's understanding. However, because the present study explored the supporting pedagogical practices on a more general level, additional research on the various approaches to scaffolding investigative activities in pre-primary technology education is needed (Marsh, 2016).

References

Alexander, R. (2020). *A dialogic teaching companion*. Routledge.

Bennett, D., & Monahan, P. (2013). NYSCI Design lab: No bored kids. In M. Honey & D. E. Kanter (Eds.), *Design – make – play. Growing the next generation of STEM innovators* (pp. 34–49). New York and London: Routledge.

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. *Art Education, 65*(2), 40–47.

Bodrova, E., & Leong, D. J. (2012). Scaffolding self-regulated learning in young children. In R. C. Pianta (Ed.), *Handbook of early childhood education* (pp. 352–369). New York: The Guilford Press.

Chappel, K., Craft, A., Burnard, P., & Cremin, T. (2008). Question-posing and question-responding: The heart of 'possibility thinking' in the early years. *Early Years, 28*(3), 267–286.

Craft, A., McConnon, L., & Matthews, A. (2012). Child-initiated play and professional creativity: Enabling four-year-olds' possibility thinking. *Thinking Skills and Creativity, 7*(1), 48–61.

Cremin, T., Glauert, E., Craft, A., Compton, A., & Stylianidou, F. (2015). Creative little scientists: Exploring pedagogical synergies between inquiry-based and creative approaches in early years science. *Education 3–13, 43*(4), 404–419. 10.1080/03004279.2015.102065

Daugherty, M. K. (2013). The Prospect of "A" in STEM Education. *Journal of STEM Education: Innovations and Research 14*(2), 10–15.

Driscoll, P., Lambirth, A., & Roden, J. (2015). *The primary curriculum. A creative approach*. London: Sage.

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing, 62*(1), 107–115.

Fleer, M. (2000). Working technologically: Investigations into how young children design and make during technology education. *International Journal of Technology and Design Education, 10*, 43–59.

Fleer, M. (2011). Technologically constructed childhoods: Moving beyond a reproductive to a productive and critical view of curriculum development. *Australasian Journal of Early Childhood, 36*(1), 16–24.

FNBE. (2016). *Finnish National Board of Education, national core curriculum for pre-primary education* 2014. Helsinki: FNBE.

Fox-Turnbull, W. (2019). Enhancing the learning of technology in early childhood settings. *Australasian Journal of Early Childhood, 44*(1), 76–90.

Ge, X., Ifenthaler, D., & Spector, J. M. (2015). Moving forward with STEAM education research. In X. Ge, D. Ifenthaler, & J. M. Spector (Eds.), *Emerging technologies for STEAM education: Full STEAM ahead* (pp. 383-359). Cham, Switzerland: Springer.

Ghanbari, S. (2015). Learning across disciplines: A collective case study of two university programs that integrate the arts with STEM. *International Journal of Education & the Arts, 16*(7), 1–22.

Harris, D., & Williams, J. (2007). Questioning 'open questioning' in early years science discourse from a social semiotic perspective. *International Journal of Educational Research, 46*(1–2), 68–82.

Harwood, C., & Compton, V. (2017). The importance of the conceptual in progressing technology teaching and learning. In M. de Vries (Ed.), *Handbook of technology education* (pp. 251–265). Springer.

Hollingsworth, H. L., & Vandermaas-Peeler, M. (2017). 'Almost everything we do includes inquiry': Fostering inquiry-based teaching and learning with preschool teachers. *Early Child Development and Care, 187*(1), 152–167.

Honey, M., & Kanter, D. E. (2013). Introduction. In M. Honey & D. E. Kanter (Eds.), *Design – make – play. Growing the next generation of STEM innovators* (pp. 1–6). New York and London: Routledge.

Jones, A., Buntting, C., & de Vries, M. (2013). The developing field of technology education: A review to look forward. *International Journal of Technology and Design Education, 23*(2), 191–212.

Kilbrink, N., Bjurulf, V., Blomberg, I., Heidkamp, A., & Hollsten, A.-C. (2014). Learning specific content in technology education: learning study as a collaborative method in Swedish preschool class using hands-on material. *International Journal of Technology and Design Education, 24*, 241–259. DOI 10.1007/s10798-013-9258-4

Kimbell, R. (1994). Progression in learning and the assessment of children's attainments in technology. *International Journal of Technology and Design Education, 4*(1), 65–83.

Larsson, Å., & Halldén, O. (2010). A structural view on the emergence of a conception. *Science Education, 94,* 640–664.

Lerkkanen, M.-K., Kiuru, N., Pakarinen, E., Poikkeus, A.-M., Rasku-Puttonen, H., Siekkinen, M., & Nurmi, J.-E. (2016). Child-centered versus teacher-directed teaching practices: Associations with the development of academic skills in the first grade at school. *Early Childhood Research Quarterly, 36*(3), 145–156.

Lindeman, K. W., Jabot, M., & Berkley, M. T. (2014). The role of STEM (or STEAM) in the early childhood setting. In L. Cohen & S. Waite-Stupiansky (Eds.), *Learning across the early childhood curriculum, vol. 17* (pp. 95–114). Bingley U.K.: Emerald. https://doi.org/10.1108/S0270-4021(2013)0000017009

Lindqvist, G. (2003). Vygotsky's theory of creativity. *Creativity Research Journal, 15*(2–3), 245–251.

Marsh, J. (2016). Researching Technologies in Children's Worlds and Futures. In A. Farrell, S. L. Kagan & E. M. Tisdall (Eds.), *The SAGE handbook of early childhood research* (pp. 485–501). London: SAGE. DOI 10.4135/9781473920859

Mawson, B. (2010). Children's developing understanding of technology. *International Journal of Technology and Design Education, 20*(1), 1–13.

Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking: A sociocultural approach.* London: Routledge.

Milne, I. (2010). A sense of wonder arising from aesthetic experiences should be the starting point for inquiry and primary science. *Science Education International, 212*, 102–115.

Milne, L., & Edwards, R. (2013). Young children's views of the technology process: An exploratory study. *International Journal of Design and Technology Education, 23*(1), 11–21.

Park, H., Byun, S., Sim, J., Han, H., & Baek, Y. S. (2016). Teachers' perceptions and practices of STEAM education in South Korea. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(7), 1739–1753. https://doi.org/10.12973/eurasia.2016.1531a

Quinn, H., & Bell, P. (2013). The goals of K-12 science education. In M. Honey & D. E. Kanter (Eds.), *Design – make – play. Growing the next generation of STEM innovators* (pp. 17–33). New York and London: Routledge.

Sawyer, K. R. (2006). Analyzing collaborative discourse. In K. R. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 187–204). New York: Cambridge University Press.

Stylianidou, F., Glaert, E., Rossis, D., Compton, A., Cremin, T., Craft, A., & Havu-Nuutinen, S. (2018). Fostering inquiry and creativity in early years STEM education: Policy recommendations from the Creative Little Scientists Project. *European Journal of STEM Education, 3*(3), 15.

Sundqvist, P., & Nilsson, T. (2018). Technology education in preschool: Providing opportunities for children to use artifacts and to create. *International Journal of Technology and Design Education, 28*(1), 29–51.

Turja, L., Endepohls-Ulpe, M., & Chatoney, M. (2009). A conceptual framework for developing the curriculum and delivery of technology education in early childhood. *International Journal of Technology and Design Education, 19*, 353–365.

Williams, J. (2012). Introduction. In J. Williams (Ed.), *Technology education for teachers* (pp. 1-14). Rotterdam, the Netherlands: Sense Publishers.

Wood, E., & Hall, E. (2011). Drawings as spaces for intellectual play. *International Journal of Early Years Education, 193*(4), 267–281.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Yliverronen, V., Marjanen, P., & Seitamaa-Hakkarainen, P. (2018). Peer collaboration of six-year-olds when undertaking a design task. *Design and Technology Education: An International Journal, 23*(2), 1–23.

Yliverronen, V., Rönkkö, M.-L., & Kangas, K. (in press). Learning everyday technologies through playful experimenting and cooperative making in pre-primary education.