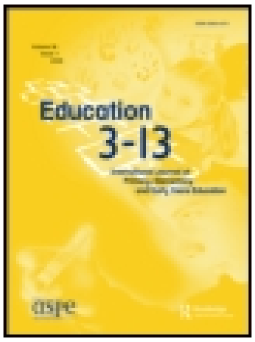

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Supporting Pupils' scientific and engineering practices in everyday life contexts at the primary school level during a project-based learning unit in Finland

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ABSTRACT
The aim of this research was to examine the potential of project-based learning (PBL) and everyday life contexts in developing primary pupils' scientific and engineering practices. Multiple data were collected in a Finnish primary school class; pupils were aged 7–8 years. The pupils' practices and creation of artifacts were videotaped and analysed using theory-guided content analysis. The analysis revealed that the designed multidisciplinary PBL unit placed within a familiar everyday life context enabled pupils to practice and communicate scientific and engineering practices supported with digital technology.

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Primary science education; home economics education; scientific and engineering practices; case study

Introduction

Multidisciplinary project-based learning (PBL) is considered to be important because pupils living in twenty-first-century society must obtain scientific literacy in order to engage with dramatic scientific and engineering breakthroughs in the future (Krajcik and Shin 2014). In a PBL, pupils collaboratively use scientific and engineering practices while making sense of everyday phenomena and designing solutions to these phenomena (Krajcik and Shin 2014). These practices, such as asking questions, investigating designs and attempting to solve problems, are similar to the practices scientists and engineers use at the professional level (Krajcik and Merritt 2012; Krajcik and Shin 2014).

In a PBL, pupils learn by researching, designing and engaging in a project embedded with everyday problems. The teacher overseeing the group helps the pupils to find information and develop problem-solving skills. Moreover, in a PBL, pupils are guided to produce an artifact (Krajcik and Shin 2014). Recent studies have demonstrated that young pupils (7–12 years) can collaboratively create tangible artifacts through scientific and engineering practices during PBL (e.g. Hasni et al. 2016). Still, little research has been done that examines the connections between primary-aged pupils' classroom activities, PBL, the collaboratively produced artifacts and everyday life phenomena. In home economics (HE) education, pupils practice everyday life skills that can be linked, for example, to mathematics (e.g. halving measurements for recipes to practice division) (Brante and Brunosson 2014). Further, in the context of HE, there is little research on primary school-aged pupils' use and learning of scientific and engineering practices.

This research focuses on how pupils engage with scientific and engineering practices within the context of a designed PBL learning unit. PBL is a suitable approach for implementing scientific and

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engineering practices to HE and science learning in the context of primary school classrooms. Storytelling can be used in PBL to contextualise a problem, to introduce the driving question and to support pupils to engage in scientific and engineering practices (Nordine et al. 2019; Vartiainen and Kumpulainen 2020). Findings that Chen, Hand, and Norton-Meier (2017) introduced into the field of science education research confirm how PBL facilitates primary pupils' involvement in scientific and engineering practices in everyday life contexts. This research attempted to examine the potential of PBL and an everyday life context to support the development of primary pupils' scientific and engineering practices.

Supporting primary pupils' development of scientific and engineering practices

Project-based approaches originate from Dewey's (1938) and Kilpatrick's (1918) work. PBL emphasises three constructivist principles: learning is context-specific (science and HE), pupils are actively involved in the learning process and pupils achieve their goals through collaboration (Helle, Tynjälä, and Olkinuora 2006; Kokotsaki, Menzies, and Wiggins 2016). PBL is a learner-driven, teacher-facilitated approach to learning and is a key strategy for fostering pupils' independent thinking skills (Bell 2010). Kokotsaki, Menzies, and Wiggins (2016) argue that PBL's success in the classroom lies in the teacher's ability to effectively motivate, support and guide students' learning. Further, the authors summarise PBL as an active and pupil-centred form of instruction characterised by pupils' autonomy, constructive investigation, goal setting, collaboration, communication and reflection within everyday life contexts.

PBL is a strategic (pedagogical) answer to the question of how to guide pupils' to and through scientific and engineering practices (Krajcik and Shin 2014). The scientific practices often integrated into PBL are similar to those that professional scientists engage in while investigating natural phenomena, such as reasoning, critical thinking and knowledge practices (i.e. questioning, observing, classifying, predicting, measuring, interpreting and analysing) (see Table 2), (Krajcik and Shin 2014). In contrast, in engineering practices, professionals apply their scientific knowledge to design and problem-solving tasks (Krajcik and Shin 2014). Defining problems, developing and using models, using computational thinking and developing design solutions are examples of engineering practices (Krajcik and Merritt 2012). There is research-based evidence confirming that primary school-aged pupils' involvement with scientific and engineering practices can help them to understand disciplinary and multidisciplinary core ideas or concepts of science; moreover, this involvement embeds pupils' practices and knowledge more deeply into their everyday lives (Miller and Krajcik 2019). Scientific and engineering practices are largely in line with globally recognised and research-supported practices of effective science learning.

Pupils' positive attitudes can be achieved and sustained by embedding lessons into meaningful, everyday life problems and projects. This is because young pupils pursue knowledge by asking questions and wondering about things arising from their natural curiosity (Eshach and Fried 2005; Nordine et al. 2019; Poirier, Remsen, and Sager 2017). Poirier, Remsen, and Sager (2017) encourage using PBL as a pedagogical approach in HE, where the aim is to develop pupils' future competencies, knowledge processing, communication, interaction and problem-solving skills. The knowledge and skills acquired in HE can easily be applied to everyday life. HE skills are often already familiar to pupils from their everyday situations, such as cleaning or preparing food at home (Granberg et al. 2017). The objectives of HE in Finnish schools include practicing tasks, creating artifacts and defining and solving problems related to everyday life (Elorinne, Arai, and Autio 2017). Multidisciplinary HE lessons are especially useful for experimenting and creating models to explain everyday phenomena (Brante and Brunosson 2014; Elorinne, Arai, and Autio 2017).

Driving questions anchored to pupils' everyday life and focus on learning goals

Pupils' engagement in learning refers to the link between the pupil and the different elements of the learning environment (Krajcik and Merritt 2012; Krajcik and Shin 2014). Previous studies have indicated that storytelling can be used in science education to introduce the phenomenon or scientific problem to be studied (Vartiainen and Kumpulainen 2020), pose the driving question and explain the complex process that incorporates real-life scientific issues from everyday life (Krajcik and Merritt 2012; Krajcik and Shin 2014; Nordine et al. 2019). Moreover, PBL applied through storytelling can pique the pupils' curiosity about the phenomenon being investigated (i.e. to illustrate the problem they must solve, the main part of the story should express the content to be learned in line with the driving question) (Krajcik and Shin 2014; Nordine et al. 2019). The story contextualises the driving question in a way that it involves pupils' everyday life experiences, is meaningful and interesting to pupils and considers any ethical issues that might arise for learners and their environment (Krajcik and Czerniak 2014; Krajcik, Phyllis, and Blumenfeld 2006). Nordine et al. (2019) suggest that using stories in PBL can increase pupils' engagement, support how they view the phenomenon and inform how they answer the driving questions.

When addressing the driving question, pupils are able to create a set of tangible artifacts with the other pupils (Erstad 2002; Krajcik and Merritt 2012; Krajcik and Shin 2014), which they can also share with each other or with the teacher (Krajcik and Shin 2014; Poirier, Remsen, and Sager 2017). Krajcik and Shin (2014) proposed that pupils learn more effectively when they develop artifacts. That said, content knowledge and skills are required to create an artifact while employing scientific and engineering practices (Nathan and Sawyer 2014). Digital technology is a major enabler for pupils to comfortably engage with the learning process in designing and developing their learning as well as creating digital artifacts (Looi et al. 2011; Sormunen, Lavonen, and Juuti 2019). Sormunen, Lavonen, and Juuti (2019) argued that in inquiry-orientated approaches here, in PBL, especially smartphones can support pupils' different abilities and interest in science learning (i.e. they can serve as powerful cognitive tools). Artifacts, such as photographs the pupils take with smartphones, can increase their social interaction in learning situations (Sormunen, Lavonen, and Juuti 2019).

Research question

As described above, research on PBL in primary school science classrooms already exists; however, little is known about pupils' engagement in scientific and engineering practices in multidisciplinary PBL projects based on authentic everyday life context. Therefore, to address this gap, the paper explores the following research question: How do scientific practices and engineering practices appear in the communications, activities and created artifacts of primary school-aged pupils?

Study context

The learning unit design was based on the educational design research (EDR) approach (Brown 1992; Edelson 2002; Sandoval 2014). The EDR method has two main goals: (1) to design a high-quality solution in the primary school classroom, (2) and to advance researchers theoretical understanding of pupils' involvement with scientific and engineering practices and the PBL unit design process (McKenney and Reeves 2018). Case study was selected as the main methodological approach of this research because of its ability to measure pupils' learning in HE and science learning during the designed learning unit (Yin 2003).

This study is conducted in the Finnish education context, which emphasises autonomy in school and teacher level. The autonomous role of teachers is supported through high quality teacher education: all primary and subject teachers are educated in five-year masters's level programmes. The implementation of this type of learning unit is therefore familiar, because teachers are main actors in the planning of local curriculum, lessons, pupils' assessment and grading (Niemi, Toom, and Kallioniemi 2012).

In this study, a multidisciplinary PBL learning unit was designed that integrated HE and science education. The design accounted for the context of the Finnish HE curriculum as described in the Finnish National Core Curriculum for Basic Education (FNCCBE 2014). The aim of HE is to develop pupils' future competencies, such as skills needed in communication, interaction and problem-solving (FNCCBE 2014). The learning unit was designed in accordance with the principles of the PBL approach; the primary school pupils' knowledge base and age were considered. The design also noted pupils' experiences investigating science and everyday phenomena and experiences working with various substances.

The learning unit

The aim for the learning unit; the competence, readiness and age of the pupils; and the class timetable were all taken into account in the design. Learning unit design was collaboratively carried out by two researcher-teachers and the pupils' own teacher. These three persons also participated in the plan implementation in the classroom setting. The written plan included transitions in the task environments, group division, task-specific instructions, and details related to safety and data collection. The pupils' own teacher acted as the responsible observer (i.e. the teacher observed the pupils' readiness to participate in the study). Prior to study implementation, permission to perform the study and include the pupils was acquired from each of the pupils' guardians. The learning unit was described to the pupils' guardians, and it was explained that the learning unit already forms part of the annual curriculum for the class. The pupils interacted with the researchers and were aware that they could at any moment tell their teacher to stop videorecording and any other documenting of their learning activities. In addition, the guardians gave informed consent for their child to participate in this study (Finnish Advisory Board on Research Integrity 2019).

Both researcher-teachers were specialised in science education for young children. They played multiple roles in the designed learning unit, but for the pupils, their role appeared only as that of teachers who could support the pupils' learning and motivate, support and guide them through co-teaching. They guided the pupils to use specific materials and learning tools suitable for the pupils' personal needs. Depending on the phase of the task, the pupils worked in small groups, in pairs or as a whole group (see Table 1). The learning unit was grounded in four major ideas supportive for learning: active collaboration, active knowledge practices, situated learning and cognitive

Table 1. Summary of the learning unit.

Year/time	Timeline	Task structures	Participants
Spring 2016/ 90 min	Storytelling 1	Pupils listen to Story 1, which introduces the guidelines for working and using a smartphone in a playful laboratory.	Teamwork: A group of 19 pupils. Implementing group work: All pupils sit in a circle on the floor. Two researcher-teachers tell the story.
	Task 1	Pupils are orientated toward the scientific practices. They observe, classify, measure and predict using different senses and a simple research tool (a pipette) to acquire information about daily materials (e.g. soap, citron, baking soda, water).	Teamwork: Small groups (9 and 10 pupils) and pairs. Implementing group work: At first, pupils sit in a circle on the floor and then stand in pairs at the tables. One researcher-teacher guides each group.
45 min	Storytelling 2	The driving question introduced in Story 2.	Teamwork: A group of 19 pupils. Two researcher-teachers direct the story. Implementing group work: All pupils sit in a circle on the floor.
	Task 2	Scientific practices and engineering practices. Pupils practice problem definition and model development for the driving question using the available cleaning cycle tools and materials.	Teamwork: Small groups (9 and 10 pupils). One researcher-teacher per group. Implementing group work: Pupils sit in a circle on the floor.
	Evaluation	Self-evaluation and answering the driving question in a narrative way. Pupils evaluate their learning and also the success of their collaboration.	Teamwork: A group of 19 pupils. Two researcher-teachers direct the evaluation. Implementing group work: All pupils sit in a circle on the floor.

learning tools (Krajcik and Shin 2014). The researcher-teachers asked the pupils to describe aloud to each other about what they were doing and learning while they were practicing. This guidance was necessary in order to observe the pupils' communication and collaboration.

The summary of the learning unit can be found in Table 1. The classroom environment was designed to be a playful laboratory equipped with simple experiment tools and materials. Ordinary safe everyday products such as soap, vinegar, baking soda, lemons, water, blueberries and stain removal products were available. In Task 1, the pupils were engaged in scientific practices, and they got help from the teacher if they needed it; in Task 2, the pupils were able to more independently use the scientific and engineering practices they acquired during Task 1 and apply their skills to solve the driving question (Table 1). In Task 2, the researcher-teachers introduced the simple cleaning cycle model that is well-known in HE education. The model represented how to perform washing based on four factors: mechanical action, chemical action, temperature and time effects. Pupils were given a paper instructing them about the cleaning cycle model featuring these four factors as well as the use of concrete tools such as a washing brush, soap, a timer and a thermometer.

In this study, storytelling refers to pre-planned, structured written Stories 1 and 2 as read by one of the researcher-teachers. The language and concepts used in the stories were designed in the context of HE and school science-learning. Both stories were written in a humorous tone and contained both fiction and facts. Before the first story, the pupils were given lab coats, which facilitated the pupils' entry into the situation and allowed the pupils to imagine how real scientists and engineers work in a laboratory, ideally encouraging them to engage in scientific and engineering practices (Vartiainen and Kumpulainen [2020] recommended). Story 1 introduced the playful laboratory, the smartphones and the substances and instruments to be studied. In Story 2, a fictional professor asked the pupils for help in finding a design solution to the following driving question: How do you get blueberry stains out of a tablecloth? The aim of the stories was to contextualise PBL via the driving question as well as motivate and offer means of communication to the pupils (Table 1). The design of the learning unit employed technology (smartphones) that is familiar to the pupils and that are appropriate for use in a learning environment. The pupils pre-tested the smartphones in two lessons during the previous week. The use of smartphones enabled the pupils to create digital artifacts such as photographs.

Data

Participants

This case study was conducted in one Finnish primary classroom in the Helsinki metropolitan area in Spring 2016 (Table 1). The designed learning unit was implemented in Grade 1 ($n = 19$), where the pupils are aged between 7 and 8 years.

Data collection

Multiple qualitative data collection methods were used for triangulation and to confirm the findings and interpretations (Yin 2003). The data consisted of video recordings (3.5 h), observational field notes and pupils' digital artifacts from the learning unit. The learning unit was videotaped via three movable video cameras and two movable voice recorders. In the data collection, the pupils used smartphones to take photos of situations they were interested in observing.

At the end of the learning unit, the pupils were asked to save four of their interesting photos on the phones. These data material can be considered as researcher-independent data creation. Almost every pupil had four photos on their smartphones ($n = 73$). Only two pupils had less than four photos. The chosen photos were printed, and the pupils explained and wrote the meanings behind the photos. The pupils' own teacher helped them to write down their explanations. The photos and written explanations contained only material produced under the guidance of the research-teacher and were taken during the learning unit. All of the research photo material was suitable and usable for the research.

Data analysis

The video data contained pupils' verbal communication and activities, such as the creation of artifacts. The preparation phase of the data analysis began with the following: (1) selecting the suitable video data, (2) making sense of the episodes when the pupils engaged in scientific and engineering practices in the data and (3) selecting the shorter units for the deeper theory-guided content analysis. The analysis process and selecting the analysis units was guided by following the pupils' verbal communication (which formed part of the scientific and engineering practices) present in the collected video data. After selecting the shorter units, the pupils' communication was transcribed, and their activities were described. This created three pages (A4) of transcripts and observation notes. The selected units (i.e. the units of analysis) contained text ranging from two words to multi-word sentences. The units of analysis were stored in a spreadsheet programme (Microsoft Excel). The units of analysis were arranged according to the pupil. Before the analysis, the pupils' names and identities were anonymised (Derry et al. 2010).

Content analysis

The first author read the units of analysis several times. By doing this systematically, an overall picture of the content emerged. The units of analysis were then analysed following the process of theory-guided content analysis (Elo et al. 2014; Mayring 2014; Yin 2003). The units of analysis were located in a coding template (Table 2), which was based on the literature review and the NRC framework (Krajcik and Shin 2014). The context and age of the pupils were taken into account when choosing the key categories – for example, the computational thinking category was excluded from the original categorisation because it is too advanced to apply to this age group (Krajcik and Shin 2014; NRC 2012). Everyday observation codes were added as they emerged from the data (Table 2). All the observation data did not meet the strict criteria for the definition of scientific observation. The key categories described the scientific and engineering practices the pupils were involved with.

Content analysis of the digital artifacts the pupils created

The artifacts the pupils produced deepened the analysis of the video data, contributing the pupils' own independent perspectives on scientific and engineering practices. All the photos and explanations the pupils generated were taken into account in the content analysis of the research material; this process followed theory-guided qualitative content analysis (Elo et al. 2014). The context and age of the pupils studied in the research were taken into account, as the photos and explanations were indeed produced by young pupils. In terms of content analyses, the researchers were highly aware that their interpretation of the texts and photos might include more than was available in the picture. The data were analysed in two cycles: (1) the data were systematically analysed to obtain an overall picture of the content, (2) the data were examined using a theoretical lens. At the beginning of the content analysis, the photos and written explanations ($n = 73$) were classified by hand. During the next stage of the content analysis, the photos and explanations were coded by numbers, which enabled a more efficient analysis. The photos and explanations the pupils created were processed as a single unit and classified according to the recognised scientific ($n = 25$) and engineering practices ($n = 54$) using the same structure of the coding template (Table 2) as in the analysis of the video material. The learning environment-class (see Table 3) comes from the analysed photos and explanations. The analysis was concluded by forming three categories, which are shown in Table 3. The artifacts of scientific and engineering practices contained at least one verb but also often a noun in their explanation. A pronoun was also included in some of the explanations. The

Table 2. Structure of the coding template and examples from the data.

Theoretical category	Codes	Definition	Examples from the data
Scientific practices	Scientific questioning	A pupil asks a question to be answered through the investigation/observation.	Pupil 5: 'Which one should I try first – water or soap?'
	Scientific observation	A pupil makes an observation in order to generate explanations related to observed phenomena.	Pupil 3: 'I think it has to be real blueberries because it looks like blueberry in colour and also smells like blueberry'.
	Everyday observation	A pupil is looking for an object or thing.	Pupil 3: 'We can definitely get stains off these tablecloths'.
	Classifying	A pupil is recognising examples and non-examples in the domain of a concept or list of attributes that can be used to distinguish examples from non-examples.	Pupil 5: 'This substance may be red cabbage or lingonberries'.
	Predicting	A pupil is using a concept or model in order to predict or suggest what will happen in a phenomenon.	Pupil 5: 'I think the soap will decide the cleaning result because my stain has become smaller'.
	Measuring	A pupil is using a standardised or non-standardised measure in order to determine the property of an object or phenomenon such as time, temperature, volume or length.	Pupil 9: 'This time refers to the time needed for cleaning the stain'.
	Analysing	A pupil is working with the data in order to present it in a way she or he can reason and interpret.	Pupil 7: 'My tablecloth stain doesn't come off, but it turns pink'.
	Interpreting	A pupil is analysing data in some way in order to recognise evidence that supports or contradicts a prediction or conclusion.	Pupil 2: 'This stain doesn't come out at all'.
	Developing a model	A pupil constructs models consistent with evidence and previous knowledge.	Pupil 6: 'The more I rub this stain, the more it spreads on the tablecloth. Hey, right?'
	Reasoning	A pupil connects a claim (presented based on observation or measurement) and evidence to show how evidence is linked to the claim by using scientific principles or critical thinking.	Pupil 7: 'You can wash stains with soap, but with dishwashing soap, stains leave better'.
Engineering practices	Defining problems	A pupil defines a simple problem that can be solved through the development of a new or improved solution or object.	Pupil 13: 'The more I rub this stain, the more it spreads [blueberry]. What do you think?'
	Using models	A pupil is using a model to illustrate, explain and predict a phenomenon.	Pupil 10: 'If the clothes are dirty and put in the washing machine, then they are most easily cleaned with hot water'.
	Developing design solutions	A pupil is developing a design solution to make everyday life work better.	Pupil 11: 'I added all the soaps together, and now, I wash the tablecloth in the given time'.

Table 3. Examples of artifacts ($n = 73$) the pupils created.

Engineering practices ($n = 25$)	Scientific practices ($n = 54$)	Learning environment ($n = 16$)
 Pupil 12: 'We washed tablecloth'	 Pupil 1: 'I Mixed'	 Pupil 15: 'Lab ingredients'

artifacts that described the learning environment contained diverse everyday life concepts and science concepts. Moreover, the pupils applied new meanings via their imaginations.

Results

During the implementation of the learning unit, the pupils engaged in many different scientific and engineering practices. The analyses provided information about how often each practice occurred during the learning unit (Figure 1). Figure 1 shows the differences between the structures of Task 1 and Task 2, which is relevant when reviewing the results. As a reminder, in Task 1, the pupils were introduced to scientific practices, and the research-teacher guided pupils in practicing scientific practices; in contrast, in Task 2, the pupils were able to use the scientific and engineering practices they acquired more independently and apply their scientific and engineering practices to answer the driving question via designing a solution (see Table 1). The radar charts (Figures 2–4) illustrate three different examples that occurred in the data. These cases offer a closer look into one pupil's communication of scientific and engineering practices during the learning unit.

Scientific and engineering practices in the designed learning unit

In Figure 1, the radar chart considers 13 related coded classes and visualises how the 16 pupils participated in and communicated about the scientific and engineering practices in the classroom. The total amount of scientific questions varied in scale 0–50. All the coded classes emerged separately of one another during either Task 1 or Task 2. The pupils' practices throughout the learning unit are limited to the Total area (see Figure 1).

Some scientific and engineering practices – such as scientific and everyday observations, classification and communication – occurred more than other practices i.e. predicting, analysing or interpreting (Figure 1). This difference in the occurrences of practices can be justified by the task structures (see Table 1), such as the observational design of teacher scaffolding of small-group or peer-learning. In contrast, the pupils' familiarity with the situation in Task 2 might have contributed to the pupils' ability to utilise their scientific and engineering practices. Scientific questioning was observed only three times in this group ($n = 16$) of pupils aged 7–8 years due to the narrow definition of the category (see NRC 2012). However, the pupils wondered about the situation in the beginning and asked, for example, if the substances and tools were real. However, a few of the scientific

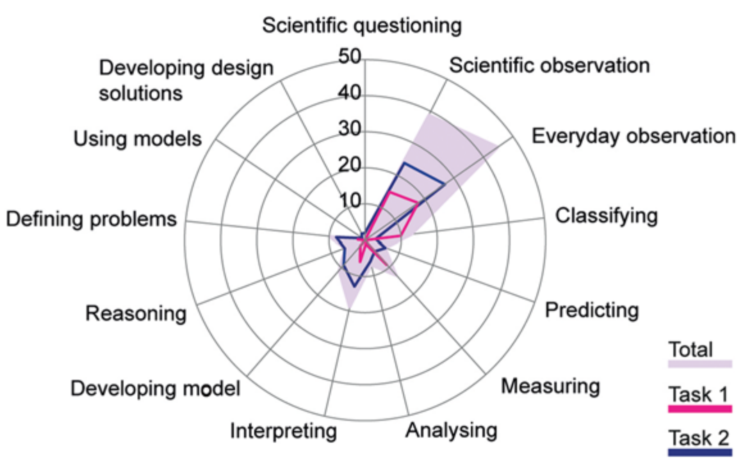

Figure 1. Overall visualisation of the data on pupils' engagement with scientific and engineering practices.

questions the pupils posed played an important role in the learning unit, as they guided the pupils' collaboration and attempt to answer the driving question.

Use of technology

The pupils' activities in a classroom were examined through employing a multiple data collection technique: the pupils' creation of artifacts and observing how they used the smartphones as part of the PBL in the collected video data. When they named their photographs, the pupils assigned multiple new meanings and explanations to the learning tools and materials and task structures. Based on the video data content analyses, the pupils' use of digital technology did not increase their verbal communication and social interaction in the learning situations; however, the smartphones and taking photographs served as independent learning tools in the PBL for this age of pupils (cf. Sormunen, Lavonen, and Juuti 2019). The digital artifacts the pupils created showed that photographing as a part of PBL learning can help primary school pupils to engage in scientific and engineering practices and increase their interest in their learning environment. The pupils used smartphone photography to successfully capture scientific observations and design solutions to the driving question because their linguistic skills would not have been sufficient to write down their observations. Using a digital tool and taking and selecting photos themselves as a part of learning in this age group provided a rich source of information about what the pupils engaged with in scientific and engineering practices during learning. Classroom observations from the video data also provided instances indicating that the pupils do self-directed learning when they used phones to take photos. These findings support previously well-known results. In other words, the pupils were able to create a set of digital photos and explanations in which they showed that their learning was guided by the driving question (Helle, Tynjälä, and Olkinuora 2006; Krajcik and Shin 2014).

Emphasis on engaging in scientific practices

In Figure 2, the radar chart gives an example of what Pupil 7 practiced and how many times (0–5) this pupil was actively involved in and communicated about scientific and/or engineering practices during Tasks 1 and 2. This pupil was very actively communicating about scientific practices with the other pupils in the group.

Pupil 7 engaged in developing a model and communicating. The pupil described washing small blueberry stains with the available cleaning cycle tools: mechanics, warm water, soap, time. In this transcript excerpt from the video data, the other pupils in the half-group stop their hands-on

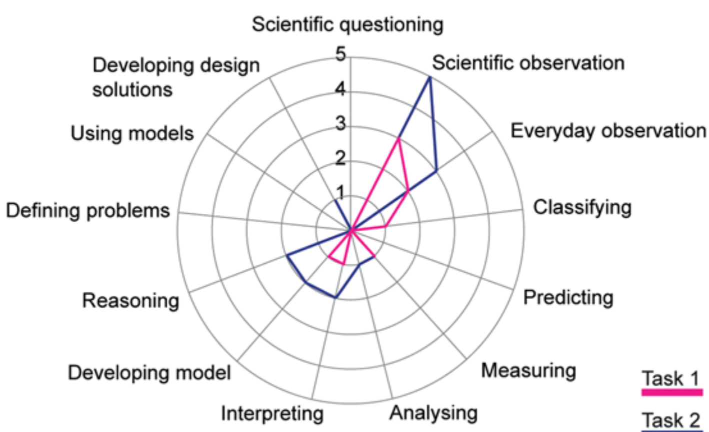

Figure 2. Emphasis on active engagement in communication and learning.

activities and start listening to what this pupil has observed while developing the model. Krajcik and Merritt (2012) emphasised that it is important for young pupils to practice and construct models that explain phenomena. Models provide scientists and engineers with tools for thinking, visualising and making sense of phenomena and experiences as well as tools to develop possible solutions to design problems (NRC 2012). It is important that pupils are able to practice models that provide a significant tool for explaining everyday life phenomena to others.

> Pupil 7: I got this stain off when there was such a small stain on this tablecloth. It was so small that yes, it came off [the pupil shows the smartphone photos to others].

Pupil 7 utilised created photos of cleaning results when the pupil communicated scientific observations and the designed solution to the other group members (Figure 2). This pupil reminded the others to use their phones to create the artifacts by showing the artifact on the pupil's phone screen. Vartiainen and Kumpulainen (2020) suggested that from the very start of their science education, young pupils should have opportunities to discuss their observations of their results. In developing a design solution to an everyday problem, Pupil 7 has broken it down into simpler components to develop and test solutions. In this case, the pupil has made scientific observations and classified and interpreted the everyday phenomenon, after which the pupil compared and proposed the design solutions to others. In the pupil's designed solution, the size of the stain affected the cleaning result.

> Pupil 7: You too should take a small stain to remove the stain.

> Pupil 7: Please remember to take photos too.

This pupil made extensive use of all the knowledge that had been learned during the designed learning unit. Pupil 7 was in active communication when the pupils answered the driving question through developing the design solution at the moment of evaluation.

> Pupil 7: With soap, you can remove [blueberry stain], but it leaves more effectively with the right detergent.

Emphasis on answering the driving question and developing design solutions

Figure 3 illustrates how Pupil 11 actively engaged in scientific and engineering practices during Task 2. The pupil engaged in developing design solutions to the driving question. Pupil 11 communicated to others that by placing all the soap on the stain and using the entire task time by following the timer, the problem can be solved. This pupil was particularly motivated by the time set up by the

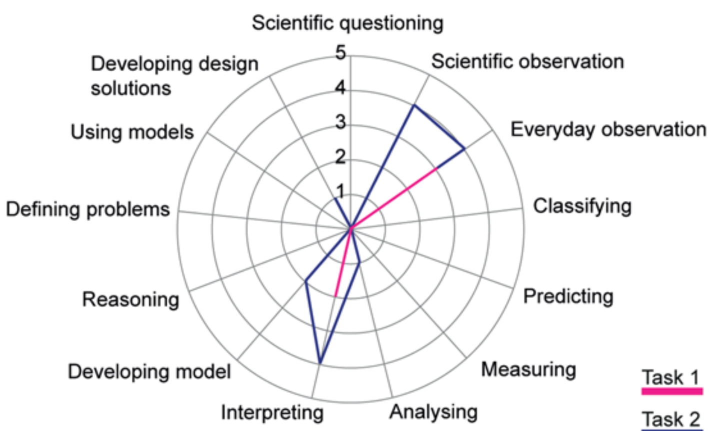

Figure 3. Emphasis on developing design solution.

timetable. This could be observed in the pupil's actions, which were fast-paced, and which utilised all the available tools and substances to develop a design solution in the experiment. This was also evident in a situation in which the pupil communicated with the group of pupils. The PBL approach seeks to solve driving questions that are meaningful to pupils in their everyday lives, and previous research has suggested that hands-on activities and real problem solving in these situations benefits pupils' learning (Walan 2019).

Pupil 11 watched how the other pupils in the group tried to solve the driving question. The pupil perhaps used this observation to form his own design solution.

> Pupil 11: I added all the soaps together, and now, I wash the tablecloth in the given time.

This pupil was able to critically evaluate own design solution and engagement in practices, while solving the driving question that was introduced in the story. The story piqued this pupil's curiosity about the driving question and acted as a motivator so that the other pupils in the group were challenged to answer a driving question (Nordine et al. 2019). Pupil 11 understood the idea of the cleaning model and its usefulness in presenting research results aloud to others.

> Pupil 11: The stain is just a little dissolved, but I will continue this cleaning.

Pupil 11 actively interpreted and analysed based on the observations and communicated with other pupils by discussing the problem and asking them for advice to solve it. Pupil 11's active listening skills enhanced the collaborative ability as well as creativity where the main objective was to enhance those skills as well as to foster collaborative ability, creativity and the ability to negotiate how to solve the driving question. Krajcik and Shin (2014) emphasised that in PBL, teachers need to guide and help pupils develop their collaboration skills, including turn-taking, listening and respecting others' opinions. The example below demonstrates that Pupil 11 is developing collaboration skills via solving the problem.

> Pupil 11: Do you use that soap? Is this soap enough?

Pupil 11 justified the designed solution to others by looking for reasoning based on scientific and everyday life observations. These reasonings received acceptance from other pupils in the group. Pupil 11 participated in collaborative discussions and scientific observations in a diverse way and presented the results of the driving question.

> Pupil 11: The cleaning result was due to the fact that the current soap was so ineffective.

Emphasis on engaging in everyday life observations

Pupil 3 serves as an example of a very common case that arose throughout the data set (Figure 4). The example was selected for this review because it features multiple participation in scientific practices. The radar chart illustrates how primary-aged pupils pursue knowledge by engaging in several scientific and engineering practices. This engagement was fostered by the storytelling and learning unit, which aroused their natural curiosity. According to Vartiainen and Kumpulainen (2020), young pupils will assign multiple new meanings to material objects and new meanings that emerge in learning situations. In their work, the pupils became capable of making observations when they used science experiment tools or created tangible artifacts.

Pupil 3 inherently showed curiosity as soon as the story and the driving question were presented to the class. This pupil wondered aloud about the tablecloth and tools in the learning environment. The pupil used the senses (sight and smell) to make scientific observations. Making this kind of scientific observation caused other pupils to imitate Pupil 3 (the video recording showed these other pupils smelling the ingredients on the tablecloth in imitation of Pupil 3). The driving question encouraged Pupil 3 to ask a scientific question based on the pupil's scientific observations:

> Pupil 3: Is that substance really blueberry on that tablecloth?

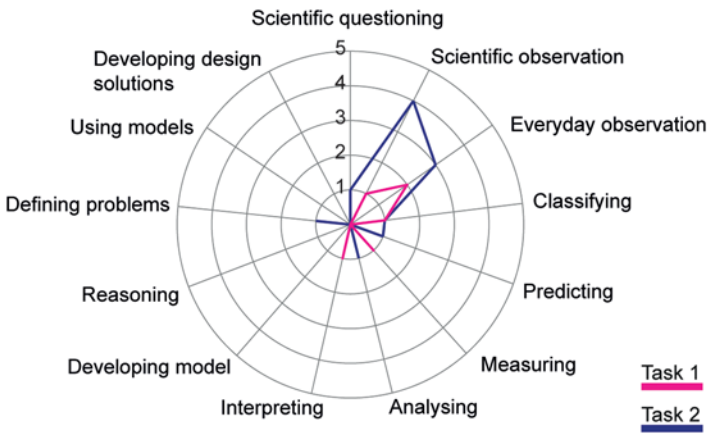

Figure 4. Emphasis on engaging in everyday life observations.

Pupil 3 guided her or his own learning independently according to the scientific practices. During Task 1, the pupil engaged with everyday life and scientific observations by classifying, predicting and interpreting things using her or his senses. This contributed to the pupil's activity in Task 2, as if the pupil was a real scientist or engineer at work. The driving question encouraged the pupil to think independently. Bell (2010) highlighted that PBL is a key strategy for pupils to become independent thinkers and learners.

> Pupil 3: I think it has to be real blueberries because it looks like blueberry in colour and also smells like blueberry.

From Pupil 3's speech, it could be deduced that Task 2 was meaningful to Pupil 3 and was suitable for the learning objectives because the phenomena and substances were familiar from the pupil's previous knowledge. The pupil's speech revealed that the carefully planned learning unit and story spurred her or his interest in an everyday life phenomenon – stain cleaning.

> Pupil 3: Blueberry does not leave anything except that my grandmother has something that will remove it.

The previous example shows that Pupil 3 was actively engaged in the construction of meanings and knowledge by answering the driving question while engaging in various scientific and engineering practices. The pupil was using concepts of science and HE and employed the cleaning cycle model in order to predict or suggest what would happen in the stain cleaning phenomenon based on the pupil's previous experience. In a similar way, Eshach and Fried (2005) argued that young pupils gain a better understanding about science concepts if they have the opportunity to use scientifically informed language in their knowledge practices.

Discussion

The aim of this research was to examine the potential of project-based learning and everyday life contexts to develop primary school pupils' scientific and engineering practices. The study gave young pupils the opportunity to immerse and engage themselves in these practices and acquire skills that they need in everyday life situations and everyday life problem-solving. The results can be briefly summarised by looking at the designed aspects of the PBL learning unit and its recognisable role in encouraging primary school-aged pupils to engage in scientific and engineering practices. This PBL learning unit was context-specific to science and HE; further, the pupils were actively involved in a learning process where their goals and learning were supported in a multi-pedagogical manner. This design included storytelling, a driving question and providing smartphone photography as a tool to communicate about scientific and engineering practices.

The successful driving question and inquiry-orientated learning were related to pupils' everyday experiences with blueberry stain dissolution using soap and water. Such everyday life phenomena and contexts could help pupils to understand that science reactions not only happen in science lessons at school, but they rather occur constantly in the everyday world (Krajcik and Czerniak 2014; Krajcik, McNeill, and Reiser 2008). Storytelling was used (Nordine et al. 2019) to provide context about everyday life. Carefully pre-planned storytelling posed the driving question, which fostered the pupils' involvement and framed how young pupils view and communicate an everyday life phenomenon when they are practicing scientific and engineering practices such as scientific observation, measurement and interpretation while defining everyday life problems and developing design solutions for stain-cleaning. Altogether, the findings suggest that everyday life context and designed learning unit can offer primary pupils' rich opportunities to practice science-related verbal communication and scientific and engineering practices. Those practices, such as scientific questioning, analysing, reasoning or interpreting are less represented in pupils' communication and activities partly because of their definitions, which are coming from secondary school science context. Therefore, they should be re-defined in the context of primary school science to meet young children's readiness to handle communication and concepts. Primary pupil's science-related speech mixes everyday and scientific concepts. For example, in situations where the pupils wondered and asked if the substances and tools were real, they are actually asking a question to be investigated. The main contribution of this study is that supporting young pupils in their natural curiosity advances their abilities to learn the process of how formulate scientific questions. This, is turn, requires the definition of scientific question in primary science context. The outcomes described above are in line with previous research on the subject (Kokotsaki, Menzies, and Wiggins 2016; Krajcik and Shin 2014; Miller and Krajcik 2019; Nordine et al. 2019). The driving question posed through the storytelling attempted to help young pupils to meet important learning goals (Krajcik, Phyllis, and Blumenfeld 2006; Krajcik and Czerniak 2014). The learning trends contained within the PBL approach have received a great deal of attention, and many studies have indicated its benefits to primary school pupils. This research provides promising results regarding pupils aged 7–8 years involved in scientific and engineering practices – specifically, their engagement is sustained through meaningful, everyday life problems and multidisciplinary projects. Although younger pupils may lack deep knowledge of science and technology, they have natural curiosity to engage with scientific and engineering practices. They wish to satisfy their curiosity, seek explanations about everyday life phenomena and develop better design solutions to everyday problems. This has significant meaning when pupils can engage in scientific and engineering practices in their early school years (Miller and Krajcik 2019).

This article reports the link between the pupil and the different elements of the designed learning unit; the learning environment, learning tasks and learning tools that are likely to affect pupils' communication. The multiple data collection technique enriched the data analysis, and the radar chart visualisations of the pupils' scientific and engineering practices enriched the interpretation of the transcription. In this article, the researchers only collected data on pupils' communications in the class; however, it can be assumed that teachers' scaffolding and discussions support pupils' PBL learning processes. Therefore, it was important that the teachers asked guiding questions or emphasised formative assessment during the inquiry process, such as, what is your question? What is your developing design solution in order to find answers to the driving question? However, further research is needed to explore teacher's role in more details.

The researchers acknowledge that there are limitations in this small-scale case study in terms of the uniqueness of the class and the participating pupils. This small-scale qualitative content analysis and the results are not intended to be generalisable. The results highlight the benefits of the PBL approach in supporting primary school-aged pupils' learning and participation in scientific and engineering practices in the context of everyday life in the Finnish school context. Despite the limitations, the results illustrate rich and multifaceted learning activities in the primary school classroom fostered by the designed learning unit.

Conclusion

The present case study described a multidisciplinary PBL project that was implemented in a class with primary school-aged pupils. In this study, multidisciplinarity is a notion that is naturally connected to HE education, where pupils acquire knowledge and skills that can easily be applied in everyday life. HE is typically described as multidisciplinary, combining practical and theoretical elements whilst aiming to develop pupils' twenty-first-century knowledge and skills (FNCCBE 2014).

The aim of this research was to examine the potential of PBL and everyday life contexts to support the development of primary pupils' scientific and engineering practices. Supporting pupils' metacognitive learning means that pupils drive their own learning through PBL related to authentic disciplinary core ideas in the context of everyday life phenomena and problems. This can spark and sustain primary school-aged pupils' interest in science and technological education, which will benefit them in the future.

In PBL, pupils can engage in real, meaningful problems and act in projects similarly to how scientists and engineers act in their projects. Within the field of science education, Krajcik and Shin (2014) proposed that this 'doing' aligns with scientific and engineering practices. The present research gives a new insight into how scientific and engineering practices can also be used in HE education, where pupils design solutions for everyday life problems. The results of this study indicate that it is necessary to build a strong pedagogical foundation as well as research-based knowledge regarding developing both science education and HE education for primary school-aged pupils.

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