Towards Project-based Science Learning: A Finnish class teacher's conceptions and implementation

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ABSTRACT

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Previous implementation research on Project-based science learning (PBSL) has mostly focussed on teachers that were provided with training or in-practice support for the implementation of PBSL. Although teacher-initiated PBSL is the most common way students are introduced to projects, little is known about the quantity and quality of project implementation in the context of teacher-initiated PBSL. This in-depth case study of one Finnish elementary class teacher's conceptions and implementation of PBSL seeks to understand how the teacher's conceptions of PBSL relates to the implementation and how the teacher's conceptions develop as a result of practical experience of implementing projects.

This case study followed Yin's (1994) recommendation for a case study design. Two interviews were conducted before and after the project implementation, they were analysed using Miles and Huberman's (1994) interactive model for data analysis. The eight-week project observations were analysed using the critical incident analysis technique. The findings are based on a comparison of the interview and observation data.

The findings show that the Finnish National board for Education's (2016) recommendations for Environmental science and the teacher's own experience formed the basis for the teacher's conceptions of PBSL. The teacher encountered many dilemmas during the implementation and was seen to develop a new understanding of some aspects of PBSL. The research concludes by pointing directions for further research and by making some practical recommendations to improve PBSL implementation in the elementary school context in Finland.

Key words: Project-based science learning, science education, Finland, elementary school science teaching

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1 INTRODUCTION

Children have an early interest in science at a very young age (Maltese et al., 2014), however, this interest is not sustained throughout their schooling (Potvin & Hosni, 2014; Microsoft corporation, 2017; Shirazi, 2017). Teachers' choice of pedagogy and the way science is presented to the students influence students' school science-related experiences (OECD 2006; Li & Jiang, 2016; Shirazi, 2017). Science education is not only important to fill Science, technology, engineering, and Mathematics (STEM) jobs in the future, but it is also important to prepare responsible and scientifically literate citizens (Krajcik & Czerniak, 2018). To attract and deepen students' interest in science is also one of the objectives for science education in the national curriculum of Finland for grades 3-6 (Finnish National board for Education [FNBE], 2016).

Teaching science through projects is seen as a way to sustain students' science interest by engaging them to explore questions that are close and meaningful to their life. FNBE (2016) also states that working methods such as hands-on learning and experiential learning should be incorporated for science teaching. Projects as a method for science learning is not new to education, however, the strength of learning through projects lies in the way all elements of PBSL come together to promote authentic science learning. Past implementation research on Project-based science learning (PBSL) has focussed on teachers that were provided with support for implementation. Very little is known about the quality of quantity of implementation when projects are initiated by the teacher, although teacher-initiated PBSL is the most common way students are exposed to PBSL (Thomas, 2000; Condliffe et al., 2017).

How teachers conceptualize PBSL is unique to each teacher (Habók & Nagy, 2016), and influences how PBSL is implemented (Rogers et al., 2010; Tamim & Grant, 2013; Cintang et al., 2017). Teachers face many dilemmas when implementing projects (Marx et al, 1994; Windschitl, 2002), although these dilemmas hinder their project implementation, they also act as opportunities for teachers to learn (Levin, 2003). Therefore, implementing PBSL results in teachers' learning. In the context of teacher-initiated PBSL, this in-depth case study seeks to understand how one Finnish elementary class teacher's conceptions of PBSL relates to the project implementation and how the project implementation results in the teacher developing conceptions of PBSL. This study offers some suggestions for further research and practical recommendations that could potentially improve PBSL implementation in the elementary school context in Finland.

This thesis begins by situating the current study in the broader research on PBSL. Then it offers a detailed overview of the case study design, a description of the projects that were implemented, data collection process and analysis methods used. Then it presents the findings of the case study. Finally, the thesis discusses the findings of the study in light of broader research on PBSL

2 STUDENTS' INTEREST IN SCIENCE

There has been an alarming decline in the number of students interested in pursuing science education (OECD, 2006; Potvin & Hosni, 2014). Europe has seen a rise in the number of students leaving science education in the past decade (Hazelkorn et al., 2015). This poses a huge challenge for the future of STEM workforce, owing to the fact that it will become increasingly hard to fill STEM jobs. International assessments such as Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS), reveal that students' science-related achievement level and motivation towards science learning is decreasing in Finland (OECD, 2016).

Research shows that students start to have an early interest in science at a young age (Maltese et al., 2014). However, this interest does not continue throughout their schooling for many (Potvin & Hasni, 2014; Microsoft corporation, 2017; Shirazi, 2017). A study by Microsoft corporation titled "Why Europe's girls aren't studying STEM" identified that girls in Europe become interested in science between ages 11 to 12, however, this interest drops between ages 15 to 16. Hence, the study identifies a four-year "Window of opportunity" to motivate and sustain girls' interest in STEM subjects (Microsoft corporation, 2017, p. 2). Other studies that are not specific to girls in STEM also point to the importance and need for sustaining students' interest in science during school (Maltese et al., 2014; Potvin & Hasni, 2014).

Many studies show that people that go on to pursue college degrees and careers in science fields are motivated by their curiosity in science and very few people associate school, teachers and classes as a factor that influenced their sustained interest in science (Maltese et al., 2014; Levrini et al., 2017). On the other hand, negative experiences with school science are more often related to factors such as teachers' choice of pedagogy and the way science content was presented to the students (OECD 2006; Li & Jiang, 2016; Shirazi, 2017). This shows that although teachers and schools may not play an important role in whether or not students go on to choose science-related college degrees or careers, they do play a crucial role in how science is experienced by students during school.

Science, in the simplest terms, is to ponder over what is not already known and try to develop explanations of how and why things happen the way it does (Krajcik & Czerniak, 2018). Science is present everywhere and children are naturally curious about the world around them, science education must try to tap into this natural curiosity. To make science engaging and interesting to students throughout schooling, school science must be relevant to students' lives and students need to engage in the process of learning science rather than learning facts about science (Blumenfeld et al., 1991; Maltese & Tai, 2011; Hasni & Potvin, 2015). That is, genuine inquiry, real-life applications, practical experience, and hands-on learning must be an essential part of science education during school (OECD, 2006; Network of Science with and for Society, 2016; Shirazi, 2017). FNBE (2016) places a lot of importance on developing students' science process skills in grades 3 to 6, yet beginning 7th graders in Finland were seen to have only naïve or mixed understanding of scientific inquiry skills (Lederman et al, 2019).

Finland aims to inspire and encourage young citizens to pursue STEM-related fields (LUMA Centre Finland, 2014). The country's national curriculum urges teachers to teach science through integrated and inquiry approaches (FNBE, 2016). Project-based science learning (PBSL) is one of the approaches that could motivate and engage students in learning science by actively involving them in the knowledge construction process (Blumenfeld et al., 1991; Thomas, 2000; Balemen & Keskin, 2018). Therefore, learning science through projects has the potential to increase students' interest in learning science. The next section offers a more detailed overview of PBSL.

3 PROJECT-BASED SCIENCE LEARNING (PBSL)

In PBSL, knowledge is not presented to the students, rather, students construct their own knowledge by engaging in a pursuit to make sense of and answer questions that are close and meaningful to their life. In a PBSL environment, students have high autonomy and freedom of choice, this shifts the responsibility of learning from the teacher to the students and in turn makes the students intrinsically motivated to learn science (Bell, 2010). PBSL is especially beneficial in science learning as students learn science content knowledge as well as develop science process skills. Science process skills refer to the skills required to arrive at scientific knowledge (Carpi & Egger, 2011). In PBSL, science process skills involve observing, investigating a phenomenon, hypothesizing, reasoning, making conclusions, developing solutions, and so on (Blumenfeld et al., 1991; Bell, 2010).

Many studies show that when PBSL is implemented consistently and with full fidelity, it positively impacts students' science content and process learning (Scott, 1994; Schneider et al., 2002; Ergül, & Kargın, 2014; Karaçalli & Korur, 2014; Erdogan et al., 2016; Rosales & Sulaiman, 2016). Studies also show that students that underwent PBSL fared better on tests that checked for science process skills which required students to apply their knowledge and solve problems (Thomas, 2000; Rivet & Krajcik, 2004; Keil et al., 2009). Studies that used students' self-reports of attitudes and motivation towards science showed that PBSL was seen to improve students' attitudes and motivation towards science (Thomas, 2000; Baker & White, 2003; Kortam et al., 2018). There is strong evidence that suggests PBSL as an approach that would not only help sustain students' interest in science but also ensure effective science learning. The next sections review in detail the historical origins and conceptualizations of PBSL.

This literature review includes articles that focus on PBL for science education which is called project-based science learning (PBSL) in this study. However, different abbreviations are used to refer to PBSL in literature, such as Science, Technology, Engineering, Mathematics project-based learning (STEM PBL), project-based science (PBS), and project-based learning (PjBL /PBL). These abbreviations are used as it is when referring to the articles in the literature review.

3.1 Historical origins of the Project in Education

The idea of a project itself is not new to education, however, it is widely agreed that Kilpatrick was the first to give the project meaning and place in the progressive education movement of the early 1900s (Knoll, 1997; Pecore, 2015). However, John Dewey's theory of pragmatism had already laid the foundation for the development of projects in schools. The idea of progressive education is rooted in the theory of Pragmatism states that knowledge gains its meaning through its practical application (Colley, 2016). Dewey regarded curiosity, action, and experience as basic conditions of learning. He introduced the concept of 'Problem' in the curriculum, he contended that children learn better through solving problems in real-life situations (knoll, 2017). Dewey rejected the idea that the curriculum should be segregated in the form of different subjects (Weiler, 2016). In his laboratory school, teachers were asked to construct a curriculum in a way that it represents real problems in society. Students were to learn by solving problems like they would in the real world (Knoll, 2017).

Kilpatrick defined the project as a purposeful activity (Kilpatrick, 1929). For an activity to be considered purposeful, it needed to satisfy two conditions: one, the child had to be able to choose the activity and would, in turn, be intrinsically motivated to perform the activity; and two, the activity had to have a purpose in the child's life (Kilpatrick, 1929; Pecore, 2015). Kilpatrick's vision of a project was criticized to be too broad. One major shortcoming of his ideology was that he used the project method to explain a philosophy of education and not a method for teaching (Knoll, 2017). The usage and value placed on the project method declined in the 1930s and some attribute the reason for its decline to the growth industrial model of education which placed importance on the subject-matter, objective-driven curriculum over a project-based, child-centred curriculum (Colley, 2016).

The emergence of the theory of constructivism coupled with the quest to motivate students to learn science and mathematics resulted in the project method gaining prominence again (Tanner & Tanner, 1980). Constructivists view knowledge as being actively constructed by humans through their experiences. Since each individual's experiences are subjective, knowledge too is subjective in nature. In addition to that, knowledge construction is personal as it is based on individual learner's prior experiences and on the environment in which the learner constructs the knowledge (Fosnot & Perry, 1996). Constructivist pedagogy is a teaching and learning theory that stems from the constructivist view of learning (Richardson, 2003). Although constructivist pedagogy specifies certain characteristics for teaching, it is not a teaching method but a descriptor for many other instructional strategies (Windschitl, 2002). Unlike earlier understandings of the project, project-based learning, rooted in the idea of constructivist learning theory is not a philosophy of education but a method used in order to realize the constructivist way of teaching and learning (Jumaat et al., 2017).

Constructivist pedagogy suggests that a cognitive conflict produces the need to learn in an individual (Pecore, 2015). Therefore, in a PBL environment students are considered to be motivated when they are cognitively engaged in a task that is relevant to their lives. Learners' prior knowledge is seen to play an active role in the development of understanding (Fosnot & Perry, 1996; Krajcik & Blumenfeld, 2005). Modern theorists believe that project-based learning must be designed in such a way that working on the projects must drive the students to learn core concepts in a given subject (Jumaat et al., 2017; Capraro et al., 2013). Aspects such as collaboration, co-working, and teamwork are important additions to projects (Jumaat et al., 2017). Lev Vygotsky considered that learning and the social context in which it happens cannot be viewed separately because learning happens first on the social level and then on the individual level (Vygotsky, 1978). Therefore, knowledge is a process through which individuals construct meaning by interacting with others and the society they live in (Kim, 2001). Learners in PBSL develop shared understanding through dialogue and discussion with others (Krajcik & Blumenfeld, 2005). The next section explains further how PBSL is conceptualized in this research.

3.2 Conceptualizing project-based Science learning

One repeatedly stated challenge with PBSL is that it does not have a commonly accepted definition or conceptualization (Thomas, 2000). This along with the fact that there are many other instructional strategies based on constructivist pedagogy that share similarities with what we call PBSL/PBL makes it harder to differentiate among the practices and to identify what real PBSL entails (Condliffe et al., 2017). It is quite impossible for PBSL to have a commonly agreed-upon definition because learning in PBSL is very context-specific (Kokotsaki et al., 2016). On the bright side, the lack of a common definition also offers a lot of flexibility for teachers to be able to use PBSL in accordance with their local contextual needs.

Despite the fact that there are varying conceptualizations of PBSL, some commonalities stand out among most of them. This section presents how PBSL is conceptualized in this research by reviewing different conceptualizations of PBSL in literature. In accordance with Condliffe et al. (2017), I use the term design principles to specify each aspect that makes up the conceptualization of PBSL. These design principles are not a criterion for judging PBSL, rather it is a way of making sense of PBSL by bringing together multiple conceptualizations. The four articles used for conceptualizing PBSL in this research were chosen based on its focus on science education, year of publication, and depth in conceptualizations.

The first column of TABLE 1 refers to the design principles that are common across all the four conceptualizations of PBSL. The commonalities are seen either in the way design principles are worded or in the way they are defined. The next part of this section explains the theoretical and practical justifications for each of these six design principles in PBSL.

TABLE 1 Conceptions of PBSL in literature

	(Krajcik, & Czerniak, 2018)	(Larmer et al., 2015)	(Grossman et al., 2019)	(Capraro et al., 2013)
Driving Questions	Driving Question	Challenging Problem, Authenticity	Authentic	Making content accessible
Disciplinary learning	Content learning	Content learning	Disciplinary	
Scientific practices	Scientific practices	Critique and revision		Engineering Design Process
Collaborative activities	Collaborative activities	Student Voice and choice	Collaborative	Helping students learn from others
Iterative and sustained		Reflection	Iterative	Feedback, revision , reflection
Creation of Artefacts	Creation of Artefacts	Public products		Making thinking visible
	Learning Technology scaffolds			Promoting Autonomy and lifelong learning

Driving Questions

Project-based learning stands out from conventional activities because of its driving questions. A driving question is the starting point for a project, and it guides the learning process throughout the project. In addition to creating a need to know something, it should be able to help students sustain their motivation throughout the project (Blumenfeld et al., 1991; Krajcik & Czerniak, 2018). The driving questions must be relevant to students' life and be broad enough so that students can ask further questions (Capraro et al., 2013; Krajcik & Czerniak, 2018). The driving question must connect content knowledge from multiple disciplines and provide opportunities for students to learn the subject matter in the process of finding an answer to the driving questions (Condliffe et al., 2017). Some researchers say that students must develop driving questions through a process of asking and refining questions (Capraro et al., 2013), while some others say that the teacher or curriculum developers can create the driving questions (Blumenfeld et al., 1991). However, it is commonly agreed that there must be room for students to develop their own approaches for answering the questions.

Collaborative activities

Krajcik and Czerniak (2018) describe collaboration in a project setting as forming "a community of learners" (p. 165). In a collaborative space, students can depend on each other, draw on each other's strengths, discuss, debate, and build on ideas (Grossman et al., 2019). Collaboration in a PBSL environment also includes collaboration between student and teacher as well as collaboration between students and the community (Krajcik & Czerniak, 2018). Teachers should deliberately plan for collaboration so that students can engage in a collaborative decision-making process (Thomas, 2000; Capraro et al., 2013; Larmer et al., 2015; Grossman et al., 2019). During this decision-making process, students must share ideas, listen to other ideas, reason, and evaluate them, and be able to provide scientific explanations for the decisions. As a result of this, students engage in a process of shared sense-making (Capraro et al., 2013; Krajcik & Czerniak, 2018).

Iterative and sustained

Grossman et al. (2019, p. 47) couple this design principle with the phrase "Cultivating a culture of production, feedback, reflection, and revision". Projects demand students' engagement for a long period of time, therefore, projects need to be iterative in nature where is are enough time and space for feedback, self-assessment, reflection and improvement (Capraro et al., 2013; Grossman et al., 2019; Larmer et al., 2015). Quality in project work is attained through thoughtful critique and revision of student work. The process of reflection in projects is very important as it enables students to learn (Kokotsaki et al., 2016). Teachers need to actively monitor student work and provide feedback where necessary (Capraro et al., 2013). Most importantly, teachers need to model the process of reflection and giving and receiving feedback (Krajcik & Czerniak, 2018; Grossman et al., 2019). These skills promote autonomy and lifelong learning in students (Capraro et al., 2013; Grossman et al., 2019), as a result, students become truly independent learners.

Disciplinary learning

PBL and PBSL are not associated with teaching content knowledge by many practitioners (Larmer et al., 2015). PBSL aims for an understanding of content Knowledge and not superficial knowing (Larmer et al., 2015). Understanding of content knowledge is attained by pushing for higher-order thinking, by orienting students towards disciplinary content while working on projects and by engaging students in practicing disciplinary knowledge (Grossman et al., 2019). Capraro et al. (2013) offer an interesting insight by suggesting that science learning should have a combination of factual and conceptual knowledge. Factual knowledge must be placed in a conceptual framework and conceptual knowledge has meaning when it is represented through factual detail. Organizing knowledge in this manner tells us that both factual and conceptual knowledge plays an important role in science learning. Therefore, when teachers plan for PBSL they must aim for both factual and conceptual understanding of Science.

Scientific practices

PBSL requires students to engage in a scientific inquiry process that imitates the way scientists conduct inquiries in the real world. Many researchers offer different methods for having students engage in the inquiry process. An important point to note is that, whatever the inquiry process used, students need to be able to actively construct knowledge (Kokotsaki et al., 2016). Some common steps that are usually part of inquiry processes are making observations, asking questions, formulating a problem, planning an investigation, collecting data, making sense of the data, arriving at a conclusion, presenting findings. Bell et al. (2005) distinguish four types of scientific inquiry based on the level to which students are independent in constructing knowledge. They are: Level 1: confirmation, Level 2: structured, Level 3: guided, Level 4: open. Students are least independent in the confirmation type and most independent in the open type. In a structured inquiry, students are provided with a research question as well as the procedure to conduct the inquiry. In a guided inquiry, students are presented with a teacher formulated question, however, students are free to design the procedure to conduct the inquiry.

A comparison between students' learning in the guided and structured inquiry type revealed that students who learned in the guided inquiry model had greater improvements in their science process and content skills (Bunterm et al., 2014). Pre-service teachers in Finland were seen to need more training and practice to ask questions during scientific observations (Ahtee et al., 2011). For a good scientific inquiry, teachers need to be able to scaffold the science content knowledge and guide the students by asking enough and appropriate questions (Capraro et al., 2013; Kokotsaki et al., 2016).

Artefacts

Artefacts are an important design principle of PBSL as it is what makes PBSL stand out among other instructional strategies. Through the process of generating an artefact, students gain knowledge. Artefacts are also representations of students' solutions or answers to the driving question, therefore, they are the representation of their learning (Blumenfeld et al., 1991). An artefact can be a tangible product, a digital presentation, a solution, or a performance (Larmer & Mergendoller, 2010). An important part of creating artefacts is also the presentation of artefacts (Larmer & Mergendoller, 2010). When artefacts are presented to the public, they motivate students and offer a form of feedback (Krajcik & Czerniak, 2018). Artefacts can also be used as a form of assessment, as they are the representation of student learning (Kokotsaki et al., 2016).

4 TEACHERS' DEVELOPING CONCEPTIONS OF PBSL

The goal of this section is to situate the present study in the broader research on PBSL. The section starts off by synthesizing previous research on teachers' conceptions and implementation of PBSL and identifies the gap in research, the second part offers a brief description of how teachers' conceptions are studied in this research, and the last part offers an overview of the literature on the implementation of PBSL which is looked at from the framework of dilemmas.

4.1 Previous research on teachers' conceptions and implementation of PBSL

Teaching science through PBL requires teachers to shift from a traditional approach to teaching and form a new understanding of teaching and learning (Rogers et al., 2010; Han et al., 2015; Mentzer et al., 2017). How teachers conceptualize the meaning of PBSL influences how they plan and implement

PBSL (Windschitl, 2002; Rogers et al., 2010; Tamim & Grant, 2013). How PBSL is implemented in turn influences the quality of students' learning (Erdogan et al., 2016). Teachers are the main drivers of new teaching approaches and play a crucial role in ensuring the success of classroom interventions (Schmit et al., 2015). Therefore, it is important to study how teachers conceptualize and implement teaching approaches such as PBSL.

The literature pertaining to teachers' conceptions and implementation of PBSL can be divided into two broad categories. One, research that studies teachers who have been provided with professional development training (PDT) to implement PBSL. Two, research that studies teachers who have not been provided with any PDT. There seems to exist contrasting findings on to what extent teachers' conceptions of PBSL influence the implementation of the same and on how teachers implement PBSL. As one reads on, one would find that these contrasting findings are due to the different ways in which teachers' conceptions and implementation of PBSL were viewed, the methodologies adopted for conducting the research, the timeline, and the context of the studies.

Habók and Nagy (2016) compared teachers' perceptions of PBL and traditional instruction through survey research. This research revealed that teachers' perceptions of PBL differed based on the teachers' experience and the type of schools they teach in. It was also seen that although PBL was the most favoured method among the teachers, it was not frequently used. Another survey research of 100 pre-service and in-service teachers conducted to understand the teachers' perspectives and experiences with PBL revealed that although teachers see PBL as an effective strategy for teaching science, their understanding of PBL may not correspond to the foundational principles of project-based learning (Hovey & Ferguson, 2014). These survey researches reveal that, although teachers view PBSL as an effective way of teaching it does not mean that they will use it in practice, nor does it mean that they understand the methodology of PBSL as a teaching strategy.

A case study conducted with three science teachers to analyse the extent to which teacher orientations of PBL in science and Mathematics influenced the implementation of PBL revealed that different orientations towards PBL resulted in different kinds of implementation (Rogers et al., 2010). Similarly, Tamim and Grant (2013) used a case study method to study three in-service teachers' definitions and the accounts of their implementation of PjBL. The study showed that teachers understood PjBL through its perceived advantages and the teachers also differed in their use of PjBL based on their belief of how the learning was best achieved. Another case study of seven teachers' perceptions and implementation of PjBL revealed that teachers had differing perceptions of PjBL and their implementation was influenced by how the teachers interpret each aspect of PjBL (Cintang et al., 2017). Based on these studies, one can say that teachers have differing conceptions of PBSL and these conceptions are related to many other factors such as their past experiences and orientations towards learning. These differing conceptions also mean that teachers have different ways of implementing PBSL.

Now, turning to studies that were conducted with teachers who were provided with PDT to implement PBSL. A collective case study of five teachers was conducted to study the teachers' understanding and implementation of STEM PBL. The study revealed that PDT helped in communicating the features of STEM PBL to the teachers, however, this did not necessarily translate in their implementation of the same (Han et al., 2015). However, in contrast to this study, a case study of 24 teachers that was conducted to explore the process of development of teachers' understanding and implementation of PBS during a three-year professional development program showed that it took the teachers at least two to three years to develop knowledge, confidence, and understanding to fully implement PBS (Mentzer et al., 2017). Both these studies offered teachers with PDT over 3 years, however, the second study periodically collected observation data from the teacher for 3 years to understand the teachers' process of learning, unlike the first study that collected one-time observation and interview data. This shows that teachers gradually develop their understanding of PBSL through practical experience.

Similarly, a case study of two teachers with many years of experience and exemplary implementations of PBSL in two urban schools in the US revealed that teachers showed improvements in their enactments through the continued practice of PBL (Tal et al., 2006). In their longitudinal study of three schools with different levels of implementation of PBSL, Erdogan et al. (2016) found that only the school that consistently implemented STEM PBL for a long period of time saw growth in student achievement. Dole et al. (2016) also confirmed that practical implementation allowed the teachers to master the logistics of PBL and gain courage in implementing it. This shows that PBSL can only be deemed effective when it is implemented fully for a long period of time.

Older case studies on teachers' conceptions and implementation also reveal similar findings. In an in-depth examination of one middle school teacher's attempt to implement PBS, the teacher was seen to develop emerging conceptions and strategies for implementing PBS through multiple cycles of implementation (Ladewski et al., 1994). Another case study of four teachers showed that the potential of PBS could be realized through the continuous enactment of projects, collaboration with other teachers, and reflecting on their enactments. (Marx et al., 1994)

The case studies presented above have a few commonalities. First, the findings itself reveal that teachers develop better conceptions and therefore improve in the implementation of PBSL through practical experience over a prolonged period. Second, all the in-depth case studies conducted were with the teachers who were provided with PDT and in-practice support in the form of a pre-planned project for the implementation. This raises some questions: What about the teachers that are not provided with PDT for implementing PBSL? How do they develop their conceptions and implementation of PBSL?

Many national curricula recommend teachers to teach science through constructivist approaches such as PBL. However, not all teachers are provided with PDT or in-practice support to implement PBL. In their review of research in PBL, Thomas (2000) and Condliffe et al. (2017) draw attention to the term teacher-initiated PBL. Teacher-initiated PBL refers to projects that are solely planned and initiated by the teachers with little or no support provided in doing so. Teacher-initiated PBL is the most common way students are exposed to PBL. However most implementation research in PBL has been conducted with teachers who were provided with a pre-packaged project to implement, very little is documented about the quantity and quality of implementation when the projects are planned and implemented by the teacher alone (Thomas, 2000; Hasni et al., 2016; Condliffe et al., 2017). For innovative educational approaches to be adopted in classrooms, teachers need to be supported to do so (Blumenfeld et al., 1991). In order to support the teachers in implementing PBSL, there is a need to first understand how teachers are currently using PBSL. This study aims to conduct an in-depth case study of one teacher’s conceptions and implementation of PBSL when the projects are completely planned and implemented by the teacher.

4.2 Researching teachers’ conceptions of PBSL

As mentioned before, earlier research reveals that although teachers think PBL is an effective way of teaching science, it does not necessarily mean that they will use it, nor does it mean that they have an advanced understanding of it. For example, Hovey and Ferguson (2014) found that although teachers knew about PBL as an instructional strategy, half of them thought that the purpose of PBL was to just create projects, this does not align with the main purpose of teaching using PBL. It was also seen earlier in the literature review that how teachers implement Projects is influenced by how they see the meaning of PBL (Cintang et al., 2017). Therefore, one can say that how teachers conceptualize PBSL plays an important role in how they implement it.

At this point in the literature review, there is a need to focus on what is meant by teachers' conceptions of PBSL and how it can be studied. PBSL is conceptualized differently by different researchers, that is, each researcher associates different aspects to PBSL and each of these aspects is explained differently (Thomas, 2000). It is only natural for teachers to have their own conceptions of PBSL especially the teachers that are not provided with any specific PDT related to PBSL. Teachers' conceptions in simple terms mean teachers' knowledge about PBSL.

Teachers' knowledge can be studied in different ways. In his review of research on conceptions of teachers' knowledge, Fenstermacher (1994) specifies that how teachers' knowledge was studied depended on the kind of questions that was being asked about teachers' knowledge. He organizes literature on teachers' knowledge according to four types of questions they answered. They are: 1. What is known about effective teaching? Studies under this question study teachers' formal knowledge, that is, knowledge as it appears in conventional behavioural sciences. 2. What do teachers know? Studies under this question seek to understand what teachers know as a result of their experience as teachers. 3. What knowledge is essential for teaching? Studies under this question seek to understand the types of knowledge required to teach competently. 4. Who produces knowledge about teaching? The studies under this question illuminate the difference between knowledge generated by university-based researchers and that generated by teachers. Each of these questions seeks different kinds of answers and hence demands a different approach to study teachers' knowledge.

This study seeks to understand what teachers already know about PBSL, therefore, it could be categorized under the question 'What do teachers know?' Research that falls under this category presupposes that teachers already know quite a lot as a result of past training and experience (Fenstermacher, 1994). The studies under this category also seek to understand teachers' knowledge without imposing any previously established theory or framework on teachers' knowledge as they place importance on the unique and contextual nature of teachers' knowledge (Fenstermacher, 1994). Few among the researchers that have studied teachers' knowledge from this perspective are Clandinin (1985) and Elbaz (1991). Clandinin (1985) describes teachers' knowledge as situated in a person's past experience, in a person's present mind and body, and in a person's future plans and actions. This kind of knowledge is carved out and shaped by situations. Similarly, Elbaz (1991) specifies that teacher's actions in a classroom are a result of the teacher's prior knowledge and experience and the action itself is the origin of the teacher's knowledge.

From this, one can understand that teachers' knowledge is formed by their past experience and knowledge, therefore it is unique in nature. This knowledge in turn influences teachers' actions in the classroom and the teachers' actions in the classroom itself influences teachers' future knowledge and action. Therefore, the teacher's knowledge is never fixed, it is constantly shaped and reshaped by the teachers' ongoing experiences. Keeping these aspects of knowledge in mind, this study places importance on the kind of knowledge the teacher already possesses about PBSL, how this knowledge influences the teacher's implementation of PBSL and how this knowledge develops as a result of practical experience. Studying teachers' conceptions of PBSL this way allows us to understand how teachers in a given context develop their conceptions of PBSL through practical experience of implementing projects while giving importance to the teacher's subjective conceptions of PBSL.

4.3 What is known about the implementation of PBSL

In a teacher's self-written article on her experience of implementing PBS for the first time, despite her satisfaction with students' science learning through PBS, she writes a long list of challenges faced with its implementation (Scott, 1994). It should come as no surprise to anyone that moving away from a traditional way of teaching science and adopting a constructive method like PBL comes with a variety of challenges for teachers, this has also been documented in many reviews done on PBL (Thomas, 2000; Condliffe et al., 2017). The implementation challenges related to PBSL varies based on the context, the depth and quality of implementation, and the school factors (Condliffe et al., 2017). Thomas (2000) in his review of the literature concluded that there is very little literature on the implementation challenges specific to PBL and recommends for its in-depth examination in different contexts.

Teachers in a project-based classroom have a lot more responsibilities and work when compared to teachers in a traditional class (Blumenfeld et al., 1991). The challenges that teachers encounter during the implementation of PBSL show itself in the form of dilemmas (Marx et al, 1994; Windschitl, 2002). Windschitl (2002, p. 132) defines dilemmas as "aspects of teachers' intellectual and lived experiences that prevent theoretical ideals of constructivism from being realized in practice in school settings". He goes on to say that these dilemmas take the form of conceptual entities for researchers, however, they take the form of questions and concerns for teachers during practice.

In his longitudinal case study of four teachers, to understand how teachers' pedagogical thinking develops over time, Levin (2003) saw that dilemmas arise when things do not go as planned or when there is a mismatch between the teachers' image of teaching and learning and the reality observed in the classroom. However, teachers' pedagogical understanding was seen to change and develop into complex ways of thinking when they were faced with dilemmas in practice. As one can see, dilemmas not only inform us about the complexities of practicing PBSL they also act as opportunities for teachers to develop their pedagogical thinking.

In his theoretical analysis of dilemmas of constructivist pedagogy in practice, Windschitl (2002) presents a framework of dilemmas that come into play when teachers practice constructivist pedagogy. This framework offers four frames of reference for the dilemmas, they are Conceptual dilemmas, Pedagogical dilemmas, Cultural dilemmas, and Political Dilemmas. Windschitl (2002) also specifies that all four categories of dilemmas presented here are important to be addressed for teachers to be able to implement constructive pedagogies effectively. Below I review the literature on the implementation challenges of PBSL and categorize them based on the dilemma they represent. Furthermore, I use this idea of dilemmas to make sense of the PBSL implementation and the teacher's developing conceptions of PBSL in this case study.

Conceptual Dilemmas

For constructivist teaching approaches like PBSL to flourish in classrooms, teachers need to have a good conceptual understanding of the practice. That is, teachers should not only know about the principles of constructivist pedagogy but should also internalize them in a way that transforms their thinking about teaching and learning (Rogers et al., 2010). Lack of such change leads to conceptual dilemmas. Han et al. (2015) perfectly describe this, but without using the term conceptual dilemma, as a gap between believing and knowing and a gap between doing and showing of STEM PBL. Although teachers thought of PBSL as a way to improve students' content knowledge in STEM, they did not believe that students would do well in summative tests. In the context of their study, Han et al. (2015) also saw that teachers incorporated PBSL simply because it was a requirement after the PDT and not because they wanted to adopt it as their teaching practice.

Conceptual dilemmas show themselves in how teachers use specific aspects of PBSL. For example, teachers who placed more importance on following and covering the curriculum content were seen to struggle with ensuring students involved in authentic investigations (Ladewski et al., 1994; Marx et al., 1994; Rogers et al., 2010). Mentzer et al. (2017) saw that teachers who thought PBS was to simply have students engage in hands-on activities developed driving questions that were limiting students' explorations, this was especially true in the case of teachers just beginning to use PBS. Conceptual dilemma was also seen in how teachers incorporate collaboration in PBSL. Most teachers considered student collaboration as an important aspect of PBSL, however, they lacked the understanding that collaboration involved more than just having students work on an activity together, it requires students to exchange ideas and negotiate meaning (Marx et al., 1994; Cook & Weaver, 2015).

Pedagogical dilemmas

Pedagogical dilemmas are the dilemmas that are associated with the difficulties involved in the practice of constructivist approaches. Some of the most common pedagogical dilemmas that were seen in the implementation of PBL were related to time, planning, classroom management, control, support of student learning, use of technology and assessments (Thomas 2000; Kokotsaki et al., 2016; Condliffe et al., 2017). These dilemmas are discussed further in this section. When asked about teachers' challenges of implementing phenomenon-based project learning in Finland in an open question on a survey, teachers expressed concerns and insecurity about their competence in designing and assessing using new approaches such as this (Tahvanainen et al., 2019). Adopting new instructional approaches is not easy even for the most experienced teachers as it results in teachers becoming novices again (Marx et al., 1994).

Teachers' content knowledge was also seen to play a significant role in the way teachers plan, adapt, and assess using PBSL (Richardson, 2003; Tal et al., 2006). The teachers with a strong understanding of the content knowledge can engage students with different interests in the content and are aware of the different ways in which the content can be learned (Windschitl, 2002; Tal et al., 2006; Mentzer et al., 2017). Therefore, although teachers find it difficult to get used to new approaches to teaching, those with strong content knowledge and experience can use PBSL more easily and effectively. Teachers' knowledge of the content was also seen to play a role in the way teachers used externally developed curricula in PBL. Teachers with strong content knowledge were able to adapt externally developed curriculum to their context in a meaningful way (Petrosino, 2004) and some cases, teachers were seen to unintentionally convert the student-driven scientific investigation to teacher-driven demonstrations and experiments after the curriculum adaptations (Fogleman et al., 2011).

Time was seen as the most common pedagogical dilemma involved in PBSL teaching (Aksela & Haatainen, 2019; Tahvanainen et al., 2019). Teachers were seen to have to decide if the time should be spent on having students explore their investigation or in covering the curriculum content (Ladewski et al., 1994). PBSL also requires much planning and preparation from the teachers' side. In Finland, teachers were seen to not be able to manage this time for planning (Aksela & Haatainen, 2019). However, fewer class teachers in Finland reported time-related problems when compared to subject teachers (Tahvanainen et al., 2019).

Important pedagogical dilemmas arise concerning student autonomy in learning using constructivist approaches. Teachers were seen to struggle in finding a balance between providing students with autonomy in projects and offering them direct instruction in specific content areas (Marx et al., 1994; Rogers et al., 2010). The student-driven nature of projects requires students to first learn how to learn in student-driven learning environments (Ertmer & Simons, 2006; Han et al., 2015). For students to become familiar with learning through projects and for it to have a positive impact on their learning, PBSL needs to be implemented consistently for a long period of time (Erdogan et al., 2016).

Teachers were seen to face dilemmas concerning assessments, they struggled when they were unable to rely on traditional tests to tell them about student leaning in PBSL (Rogers et al., 2010; Rivet & Karjcik, 2004). Teachers were also seen to be pondering about how they can design and use assessments to measure students' content learning as well as their science process learning (Rogers et al., 2010). Pedagogical dilemmas were seen in the way teachers used technology in PBS, teachers were seen to mostly use technology as an instructional tool rather than a cognitive tool (Marx et al., 1994). Pedagogical dilemmas were also visible when the students engaging in group work did not participate equally, this left the teacher wondering how much of the basic knowledge students were learning in their groups (Rogers et al., 2010). Student academic readiness to learn through the PBSL approach was another factor that created pedagogical dilemmas in teachers. They found it hard to incorporate strategies like PBSL when students were not academically prepared or competent to do so (Han et al., 2015; Tahvanainen et al., 2019).

Cultural dilemmas

Classroom practices are situated in the larger context of the school and these practices are influenced by the school culture and organization (Windschitl, 2002). Implementation of PBSL is influenced by the school-related factors, teachers face cultural dilemmas when the school culture is not in alignment with the fundamental principles of PBSL (Ravitz, 2010). For PBSL to be implemented effectively, it is not only enough for the teachers to shift their beliefs and practices of teaching and learning, but the students, parents, school management also need to go through a shift in the way they see teaching and learning (Condliffe et al, 2017). Teachers in schools that had adopted the project-based approach as a philosophy for teaching and learning were seen to be more enthusiastic and motivated to teach using PBL (Toolin, 2004). An unsupportive school environment can serve as a major impediment to novice teachers' intentions and desires to implement PBL (Marshall et al., 2010). Other school-related challenges such as an inflexible school calendar, insufficient space in the classroom, lack of resources and inability to collaborate with other teachers were factors that hindered teachers' implementation of PBSL (Cook & Weaver, 2015).

Political dilemmas

Political dilemmas arise when teachers are expected to practice constructivist approaches to teaching when the policy documents do not support them in doing so. In contexts where standardized testing is mandatory, a dilemma arises when teachers must decide between having to prepare students for the standardized tests and encouraging students' autonomy in learning (Marx et al., 1994; Rogers et al., 2010; Cook & Weaver, 2015; Mentzer et al., 2017). In a non-threatening environment where teachers did not have the burden to prepare students for high stakes tests and covering curriculum content, teachers were seen to be able to offer autonomy to students and promote experiential learning (Dole et al., 2016). Political dilemmas were also seen in situations where teachers have had a large class size, fixed resources and incompatible technology (Blumenfeld et al., 1991).

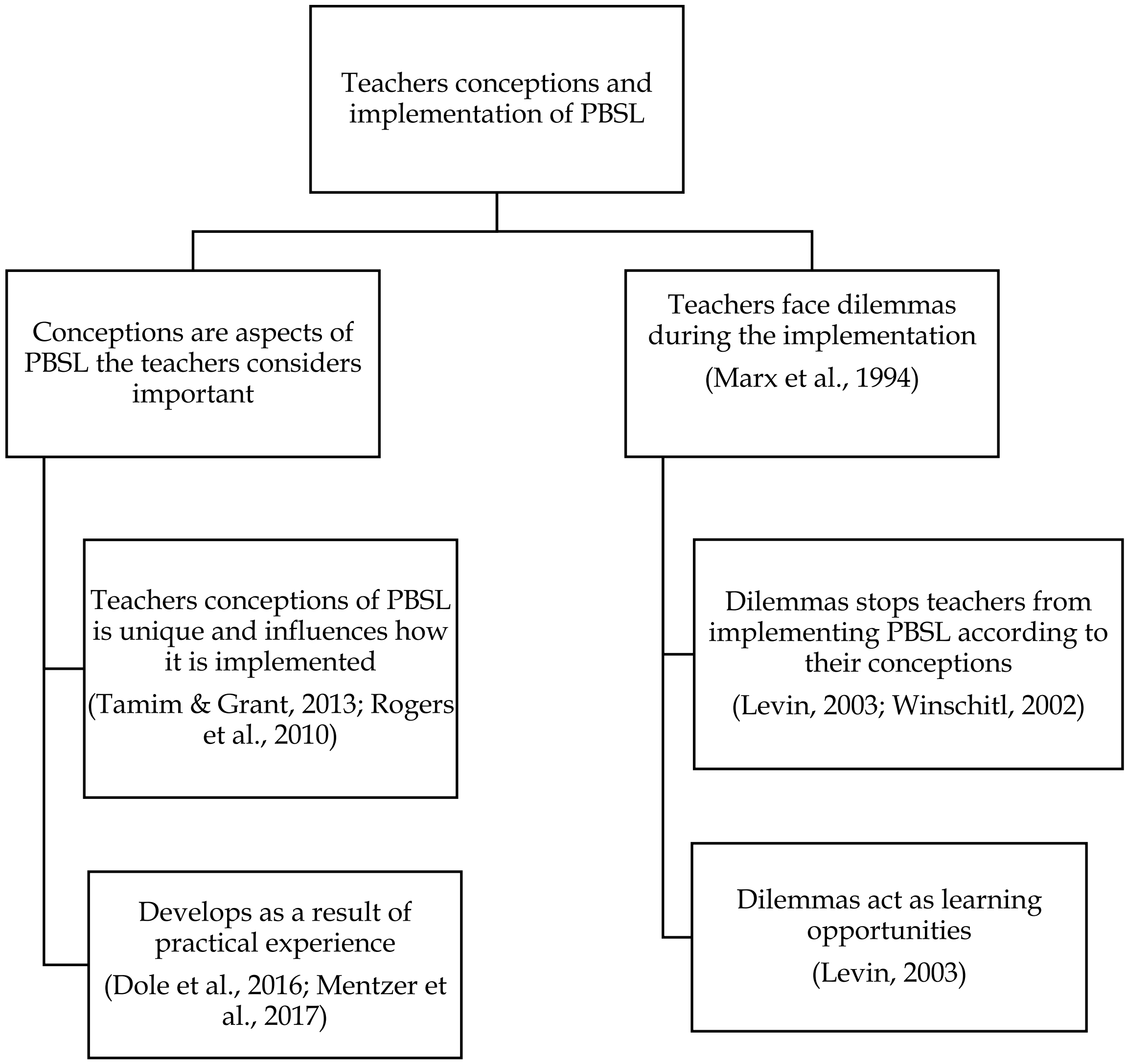


FIGURE 1 Framing the literature review

In conclusion, this literature review has identified the need for using Projects to teach school science and the importance of studying teacher-initiated PBSL. Then, it went on to review what is already known about teachers' conceptions and implementation of PBSL. The literature review also established how the teacher's conception of PBSL is going to be looked at in this research. Finally, it addressed the most common dilemmas faced by teachers when implementing PBSL, this is done by following Windschitl's (2002) framework of dilemmas. FIGURE 1 offers a representation of the main theoretically driven concepts that guide this research.

5 THE CASE STUDY

The present study is a single case study of teacher-initiated PBSL implemented by one teacher in a Finnish elementary school. The larger research task of the study is to understand how the teacher conceptualized and implemented PBSL when the project is initiated by the teacher with no support or guidance for the implementation. A case study approach is best suited for this research as it offers a possibility to perform a comprehensive, holistic, and in-depth investigation of a complex issue in its context (Creswell, 2007). Stake (1995) proposes the case study as a decision on what is to be studied. He describes an instrumental case study as a type of case study where the focus is on an issue or concern, and one bounded case is selected to illustrate this issue (Creswell, 2007). I borrow this understanding of cases to define the case in the current research. Therefore, the current case study follows a single instrumental case design where the focus in on the implementation of PBSL when the projects are initiated solely by the teacher. The next section explains how the case was chosen.

5.1 Choosing the case

Projects are an essential part of the Finnish National Core Curriculum for basic education, therefore, teachers are expected to do at least one project with the students during an academic year. More detailed information about the Finnish educational context is provided in section 5.3. As mentioned earlier, I use Stake's (1995) definition of a single instrumental case study. The central issue/concern that I wanted to study was that of teacher-initiated PBSL, so the bounded case that illustrates this issue could be any teacher who is doing projects with the students. The only two conditions that needed to be satisfied were that the teacher had to be doing a science-related project and the teacher should be interested to participate in the study.

I started looking for teachers who might be willing to take part in my study at the end of the 2018-2019 academic year. An initial email requesting participation in the study was sent out to three elementary school teachers in Finland. Among the three teachers, two teachers were interested in participating in the study. Further discussions with the teachers about the feasibility and timeline of research started at the beginning of the 2019-2020 academic year. I eventually decided to go with just one case. The reasons for this are, one, I did not have a strong justification for doing multiple case studies. Two, as I was a single researcher gathering and analysing the data for the research, it seemed like I would not be able to do justice to the research if I conduct two case studies. The teacher that participated in this study is a class teacher in a Finnish elementary school. As a class teacher, she taught a range of subjects such as Finnish, English, Maths, Environmental science (ENS), History, and Arts. The projects she conducted were for ENS with students who were older than 10 years. A detailed account of the projects conducted in the case study is provided in section 5.4.

5.2 Case study Design

Yin (1994) offers clear guidelines for designing a case study plan, which he calls a case study protocol. A case study protocol primarily acts as the logic that connects the data collected to the initial research questions and finally to the conclusions (Yin, 1994). Developing a sound case study protocol is also a way of increasing the reliability of the case study (Yin, 1994). Therefore, a sound case study protocol was developed for this research before the start of the study. While the main research task of this study remained constant throughout the research process, the specific research questions changed slightly as the data collection progressed. This is mainly because I did not have any control or knowledge about what kind of projects were going to be implemented until the very beginning of the projects. The case study design includes five components, they are: 1) study questions 2) propositions 3) unit of analysis 4) the logic for linking data and propositions 5) the criteria for interpreting findings. These components are discussed below.

Study questions

1. How did the teacher's conceptions of PBSL relate to the implementation?
2. How did the teacher's conceptions of PBSL develop as a result of practical experience of doing projects?

Study Propositions

Propositions help with identifying the relevant data required for the research. Based on the review of literature I arrived at two theoretical propositions. They are, **Teachers' conceptions of PBSL influences how PBSL is implemented** and **Teachers' conceptions of PBSL develop as a result of practical experience**

Unit of analysis

The unit of analysis determines the focal points of the case and defines what the case is about. This research uses two units of analysis. The first one is the teacher's conceptions of PBSL and the other one is the projects that were implemented by the teacher.

Logic linking data and research and Criteria for interpreting findings

The third and fourth aspects of the case study protocol represent the data analysis steps involved in the case study and are said to be the least developed aspects of the case study research (Yin, 1994). At the beginning of this research, I did not have a well-formed plan on how I was going to use the data gathered. However, I had a general idea of wanting to organize the interviews in the form of a concept map to be able to compare and find connections between them. The goal of the analysis process was to be able to compare the data gathered in the observations and the interviews. By doing this I would have been able to test the propositions of the study and answer the research questions. In section 5.6, I offer a detailed explanation of the analysis process.

5.3 Finnish school context

This section offers a brief overview of the National Core Curriculum in Finland, the structure of ENS education for grades 3-6 and about teachers and teaching in Finland.

The National core curriculum for basic education

Finland released the National Core Curriculum for basic education in the year 2014. The core curriculum mainly defines the mission, values and structure of basic education. It also defines the objectives and content to be learned in each subject. The core curriculum is a national regulation prepared and issued by the Finnish National Board of Education and all municipalities are expected to prepare their own local curricula in compliance with the core curriculum (FNBE, 2016). The local curriculum is expected to implement the national targets but is also expected to take into consideration the local contextual needs. However, the municipality and schools have considerable freedom to interpret the curriculum as they want (Lähdemäki, 2019).

The idea that students are active agents of their own learning forms the basis of the core curriculum's conception of learning (FNBE, 2016). One aspect of the core curriculum that is worth noting in relation to this study is that of the Transversal Competences. The seven transversal competences stated by the core curriculum are designed in order to prepare students for the changing world. Transversal competences represent the values and attitudes required for using the knowledge and skills from different fields for personal growth, study, work, and civic activity (FNBE, 2016). These competences are part of everyday teaching and learning activities of the school. These competences also clearly align with the need for incorporating teaching methods like project-based learning in schools. The seven transversal competences stated by the core curriculum are Thinking and learning to learn (T1), Cultural competence, interaction and self-expression (T2), Taking care of oneself and managing daily life (T3), Multiliteracy (T4), ICT competence (T5), Working life competence and entrepreneurship (T6), Participation, involvement and building a sustainable future (T7).

Environmental science in grades 3-6

In Finland, ENS is considered an integrated subject where the students learn subjects like Biology, Physics, Chemistry, Geography, and Health education, with a focus on sustainable development (FNBE, 2016). The core curriculum suggests using working methods such as learning by doing and experiential learning to teach ENS (FNBE, 2016). The core curriculum also specifies that the students' ability to carry out research projects are essential for the achievement of the objectives (FNBE, 2016).

In grades 3-6, ENS is structured as units through which the students learn about their surroundings, themselves, and their actions as members of the community (FNBE, 2016). The core curriculum provides 19 objectives of instruction and assessment criteria for ENS in grades 3-6. These objectives of instructions and assessment criteria are grouped in three categories, they are (i) Significance, values, and attitudes- students develop values and attitudes required to act as responsible citizens in promoting sustainable development; (ii) Research and working skills- students develop skills required to carry out research projects and scientific investigations; (iii) Knowledge and understanding- students develop knowledge on content related to ENS (FNBE, 2016). Each municipality is expected to develop a more concrete and actionable curriculum in accordance with the local contextual needs. A local curriculum is, therefore, a pedagogical tool that helps the teachers plan their daily work. The teacher in this study uses the local curriculum extensively to guide her own planning, teaching, and assessment in ENS.

The core curriculum offers a versatile means of assessing students in ENS. In addition to assessing students' content knowledge in ENS, the core curriculum specifies the importance of assessing the students' process of learning (FNBE, 2016). Hence, it can be said that the core curriculum not only places importance on developing science knowledge but also on developing students' scientific process skills and the values and attitudes necessary for students to play an active role in promoting sustainability in the society.

Teachers and teaching in Finland

Teaching is a highly respected profession in Finland. Teachers are required to be educated at the master's level and therefore are expected to be autonomous and reflective academic experts (Toom & Husu, 2016). Because of these reasons, teachers are not subject to any inspection or evaluation. Teachers also possess pedagogical freedom to make decisions on the kind of materials and methods to use for teaching (Lavonen & Juuti, 2016). While the teacher in this study followed the local curriculum guidelines to plan the project, she used her pedagogical freedom to choose materials and sources from outside the textbooks.

The lower comprehensive school in Finland is from grades 1 to 6. The class teachers in primary schools are qualified to teach 13 school subjects. In their class teacher education program at the universities, primary school teachers generally have about 12-18 ECTS credits for science education (This number differs for each university). The science education courses in primary school education programs at the universities place more emphasis on pedagogy and not enough time is spent on learning the subject knowledge related to science (Evagorou et al., 2015; Lavonen & Juuti, 2016). This means that the class teachers in primary school are not specifically trained to be science teachers and therefore, they may not have a very deep understanding of science concepts.

5.4 The projects

Two projects were conducted in the course of three months. The first project was about water surface tension (WST) and the second project was about electricity. The project classes took place once every week. Since the teacher was a class teacher, she had the flexibility to combine multiple classes for the project when necessary. Each class was for 45 mins, however, the days when the students had three classes for a project, they only spent 85 mins on the project because of a lunch break in the middle. The main focus of doing the projects was to have students learn about concepts of WST and electricity by conducting scientific investigations. This is also a recommendation offered by the Finnish National Core Curriculum for basic education. The two sections below offer an overview of the projects that were conducted in the class.

5.4.1 Water surface tension (WST)

This first project was to be a shorter pre-project, it was conducted in order to prepare the students for the main project. The WST project was part of a longer unit on water, during this unit the students explored different kinds of water lands and properties of water through a field trip and activities. The students were going to continue learning about water later during the academic year. For this study, I only observed the project on WST. The WST project was spread out to happen over three weeks. During the project the students practiced skills required for a scientific investigation such as predicting, documenting the method, observing, noting down the results, and explaining the cause. To help with the investigation, the students were given an investigation form that had columns named equipment, method, prediction, results, and conclusion. This form was used not only as a tool to help students learn the skills of an investigation but also to help students build their understanding of the concept of WST. The WST project had three important parts as mentioned in TABLE 2. A detailed account of the projects can be found further in this section.

TABLE 2 Water surface tension Project

Week	classes	Activity
Week 1	3	Students experience the phenomenon through experiments
Week 2	1	Student develop a shared understanding of the phenomenon
Week 3	1	Student gain a deep understanding of the phenomenon with the help of the teacher

The project began by having the students perform three experiments related to WST. The experiments required students to observe what happens when they drop different things such as peppers, paper clips, paper fish, and soap into water (see e.g. FIGURE 2 & FIGURE 3). At this stage, the concept of WST was not revealed to the students. They were to perform the experiments, observe what happened, and start to think about why it happened. The goal was to have the students encounter problems and ask questions about the phenomenon before learning about the concept.

FIGURE 2 Paper clip experiment.

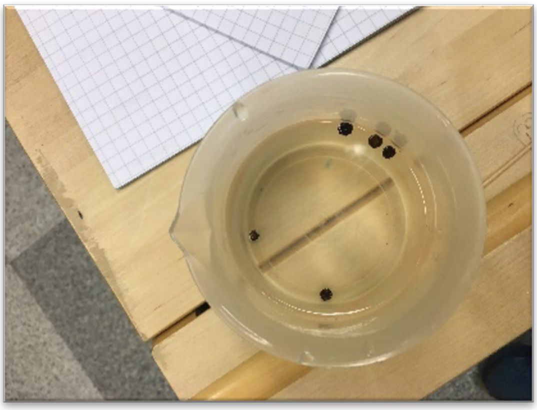


FIGURE 3 Pepper and soap experiment

After the students had performed the experiments and filled the investigation forms, the next step was for students to develop a shared understanding of the phenomenon they had observed. For this, the students were asked to discuss and compare their investigations in their respective groups. The students then had to write their conclusions on the board. After going through all the conclusions, the students had to vote for the conclusions they thought was most convincing. By doing this, the students were able to think about reasons for the phenomenon. They noticed that there can be different observations and conclusions and thought about the best possible conclusion. On the third day of the project, the concept of WST was introduced to the students with the help of a video. During this class, the teacher first explained the concepts of WST to the students and then helped the students make connections between the concept of WST and the experiments they had conducted. The project ended with students making connections of WST to some real-life situations.

5.4.2 Electricity

The electricity project was a bigger project and it happened over 5 weeks. Students continued to practice the skills of scientific investigation in this project too. The content for this project was chosen from the local ENS curriculum. There was no predetermined plan for the project, the plan was made and changed according to the students’ progress and needs in the project. A brief overview of what happened during the project can be found in TABLE 3.

TABLE 3 Electricity Project

Week	Lessons	Activity
Week 1	3	Students gather their ideas about electricity and electricity safety issues
Week 2	1	Students construct simple electric circuits using real equipment
Week 3	3	Students construct parallel and series circuits using Circuit construction kit DC (CCDC)
Week 4	3	Students explore and test the conduction properties of various materials
Week 5	1	Assessment

The goal of the first project class was to have students gather their ideas on what they already knew about electricity, to add to what they already know and to help them connect their ideas to real-life scenarios. After watching a video on electricity, the students were asked to think about the dangers of electricity in their daily life with the help of multiple exercises. These exercises were taken from a teachers' resource sharing website. The students were presented with a picture of a living room with many dangerous electrical appliances. The students had to recognize the dangers that these appliances could cause. Next, the students had to design a poster featuring one electricity safety message. Finally, the students were presented with a reading comprehension text that contained information about the history of electricity. After the reading, the students had to answer a worksheet related to the text. However, the students did not have enough time to complete the worksheet, so they were asked to do it at home.

In the second week of the project, the students had to figure out how to get a light bulb to light up and as a result learn about the essential components of a circuit. For this, the students were provided with a book that had instructions on how to construct circuits and a kit that contained all the necessary equipment to construct a circuit. While constructing the circuits the students needed to make a note of what supplies they used and what they did with the supplies. During the activity, the students constructed circuits with a light bulb and a buzzer (see e.g. FIGURE 4). Since the equipment in the kit was not dangerous, the students were allowed to try many different combinations. This allowed the students to experiment, observe, and ask questions about circuits and their components.

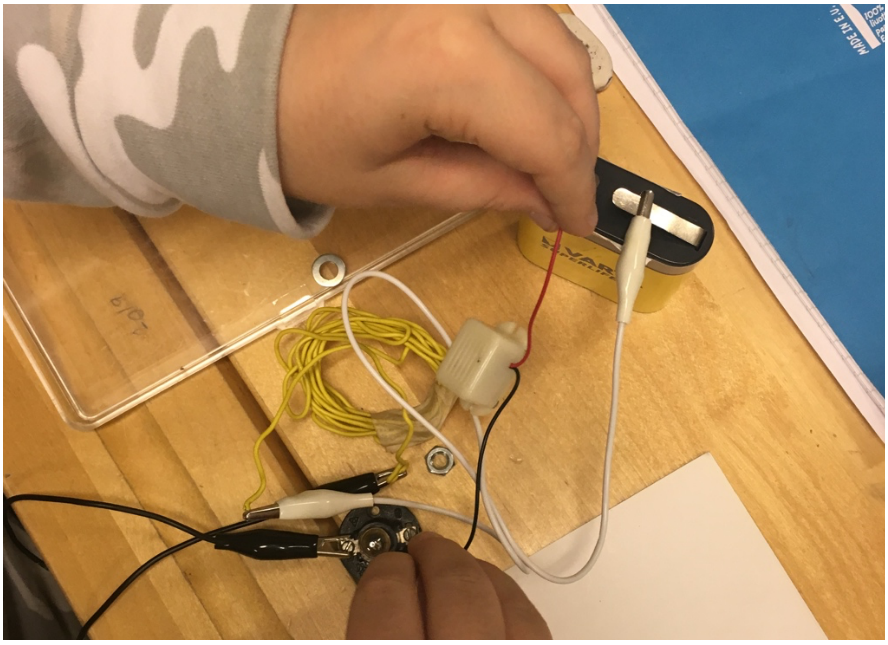


FIGURE 4 Students trying to make the light and buzzer work

In the third week, the teacher wanted the students to learn the scientific symbols for representing electric circuits and to learn how to construct and measure the voltage and current in parallel and series circuits. For this, a booklet was used for exploring electric circuits further. The class began by introducing the symbols used to represent each component of an electric circuit. The students learned the symbols and completed a few activities where they had to label the components of an electric circuit and draw circuits using scientific circuit symbols. After this, the students were introduced to the concept of series and parallel circuits with the help of a video. After some discussion on the different types of circuits, the students were shown how to construct circuits using an online application called Circuit construction kit DC (CCDC). Finally, the students had to construct series and parallel circuits with the help of the instructions provided in the booklet (see e.g. FIGURE 5). They also had to measure and note down the voltage present in the circuits.

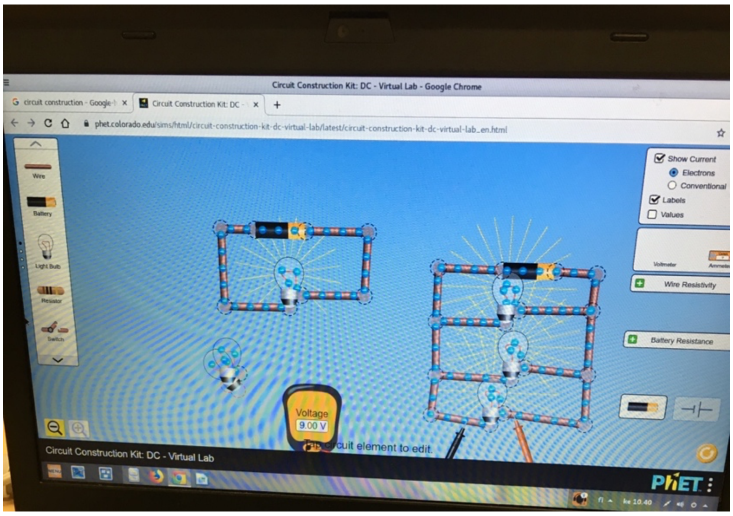


FIGURE 5 Students constructing parallel and series circuits on CCDC

In the fourth week, the students and the teacher went through the topic of Parallel and series circuit again because the students needed more support with it. The class started with a video that explained voltage and current in parallel and series circuit. After some discussion, the teacher and students together measured the current and voltage in series and parallel circuits and filled the table in the booklet with the readings. Next, the students had to plan and execute their investigation on conductors and insulators with the help of an investigation form. The students first needed to construct a circuit using the circuit kit, then they had to pick one material to test its conducting properties (see e.g. FIGURE 15). Before the start of the investigation, the students had to write down a hypothesis about the conduction properties of the materials and then test the hypothesis through the investigation. Finally, the students had to write down if their hypothesis was right or wrong and the reasons for it. In the last week of the project, the students had an assessment that tested everything they learned through the Electricity project.

5.5 Data collection

A researcher's paradigm acts as the lens through which the researcher understands reality, builds knowledge, and gathers information about the world (Tracy, 2013). I used the interpretive paradigm to guide my data collection and research methods. Through an interpretive paradigm, a researcher tries to see social action through the actor's standpoint and therefore the researcher strives to gain an empathetic understanding of other's viewpoints, beliefs, and understanding (Tracy, 2013). The interpretivists believe that the human perspective is subjective and therefore reality can have many meanings (Wahyuni, 2012). In this research, PBSL is studied from the participant's standpoint. I consider the teacher's conceptions of PBSL and the way it is implemented as subjective to each teacher and is bound to change based on the teacher's experiences. Therefore, teacher's conceptions of PBSL acts as the starting and the ending point of my data collection and interpretation.

Yin (1994) suggests the incorporation of three principles for data collection in case studies – to use multiple sources of evidence, to create a case study database, to maintain a chain of evidence. Case studies generally rely on gathering data from multiple sources and this is also the strength of a case study (Yin, 1994). Gathering evidence from multiple sources allows the researcher to triangulate the evidence by developing converging lines of inquiry (Yin, 1994). Of the six sources of evidence suggested by Yin, I used interviews and direct observations as my main sources of evidence. In addition to that, I also gathered photos of student artefacts and assessment papers. The data was gathered with the aim of being able to answer the research questions by comparing different sources of evidence. TABLE 4 offers a brief overview of the timeline and the type of data collected for this research. The number of photos taken is not mentioned in the table as I clicked many photos throughout the course of the projects and I just used them for reference, some of the images are attached in section 5.4 named 'The Projects' and in section 6 named 'Findings'.

TABLE 4 Data collected

	Time	Amount of data	
Pre-interview	5/9/2019	1 hour, 12 pages, 6840 words	• To understand what the teacher knows about PBSL
Classroom observations	6/11/2019-18/12/2019	8 weeks (~16 hours)	• To get an account of what happened in the project
Post-interview	20/12/2019	1.5 hours, 16 pages, 9967 words	• Stimulated recalls with the help of pictures of student artefacts • Teacher's reflection of the projects

All the data collected for this research was stored in the private drive on the university computer and will be archived in the university database by the end of the year 2020. I have tried to maintain a chain of evidence in the research by describing in detail, the steps I have taken in each step of the methodology. In the following two sections I explain further the data collection methods used.

5.5.1 Interviews

Interviews are one of the most important sources of evidence in a case study research (Yin, 1994). Tracy (2013) describes interviews and fieldwork as the yin and yang of qualitative research, which means, interviews and fieldwork complement each other in a qualitative inquiry. Interviews in this case study are very essential as it helps understand the teacher's subjective experience and viewpoints of the projects. This, in turn, helped my own understanding and interpretation of the projects that were observed.

Two interviews were conducted as part of the research. One, before the projects started and the other after the projects were completed. The motivation for the study was informed clearly to the teacher before the interview. The goal of conducting the two interviews was to be able to compare both the interviews to understand how the teacher's conceptions of PBSL developed as a result of the practical experience of implementing the project.

The first interview was conducted after gaining signed consent from the teacher and verbal permission from the school principal. Both the interviews were conducted after the school day in the classroom where the teacher works. The interviews were recorded in a manual recorder borrowed from the university. The interviews were transcribed immediately after they were conducted. To speed up the process of transcription, a free version of the application called Express scribe which is available on the university system was used.

The Pre-interview

The goal of the pre-interview was to learn what the teacher knows about PBSL. The interview was unstructured, however, I had prepared a list of topics to ask the teacher if it did not come up in the interview already. These topics were taken from the literature related to PBSL. Unstructured interviews are more flexible and organic in nature and they allow for an interviewee's emic understandings to emerge and therefore, the interviewee's complex viewpoints can be heard through an unstructured interview (Tracy, 2013). This flexibility was required at this point in the research as the pre-interview was a chance for me to get to know how the teacher conceptualizes PBSL.

The Post-interview

The post-interview took place after the project implementation was completed. The questions for the second interview was formed as the second project was coming to an end. The observations and my reflections of the observations had already made it quite clear how the second interview needed to be approached. The critical incidents identified during the observations helped me form questions for the post-interview. The second interview was a structured interview. As one would notice, the format of the pre-interview differs from that of the post-interview, yet, both the interviews offered grounds for comparisons.

The primary goal of the pre-interview was to understand how the teacher conceptualized PBSL, that is, what aspects of PBSL did the teacher think was important. Whereas, the goal of the second interview was to understand how the teacher's conceptions developed in these specific aspects. However, no direct questions were asked in relation to these aspects, instead, the interview sought to know if the teacher still considered the same aspects from the pre-interview as important? How does she talk about these aspects of PBSL? and Did she develop an understanding of some new aspects of PBSL? How the interviews were compared becomes clearer in section 5.6.

The post-interview interview consisted of four parts as shown in FIGURE 6. The first part of the interview began by asking the teacher to narrate the two projects, this was done to have the teacher recollect the incidents of the project. After the narration, I used a stimulated recall interview (SRI) approach with the help of pictures of two critical incidents taken during the project. SRI calls upon the participant to reflect upon their activities. It helps the researcher understand what the participant counts as important and how the participant chooses to convey the information (Dempsey, 2010). After presenting the two pictures one by one, I asked the teacher to tell me her experiences during the critical incidents. Using the SRI approach was very beneficial during this part of the interview as it informed me about the teacher's perspectives of the incidents.

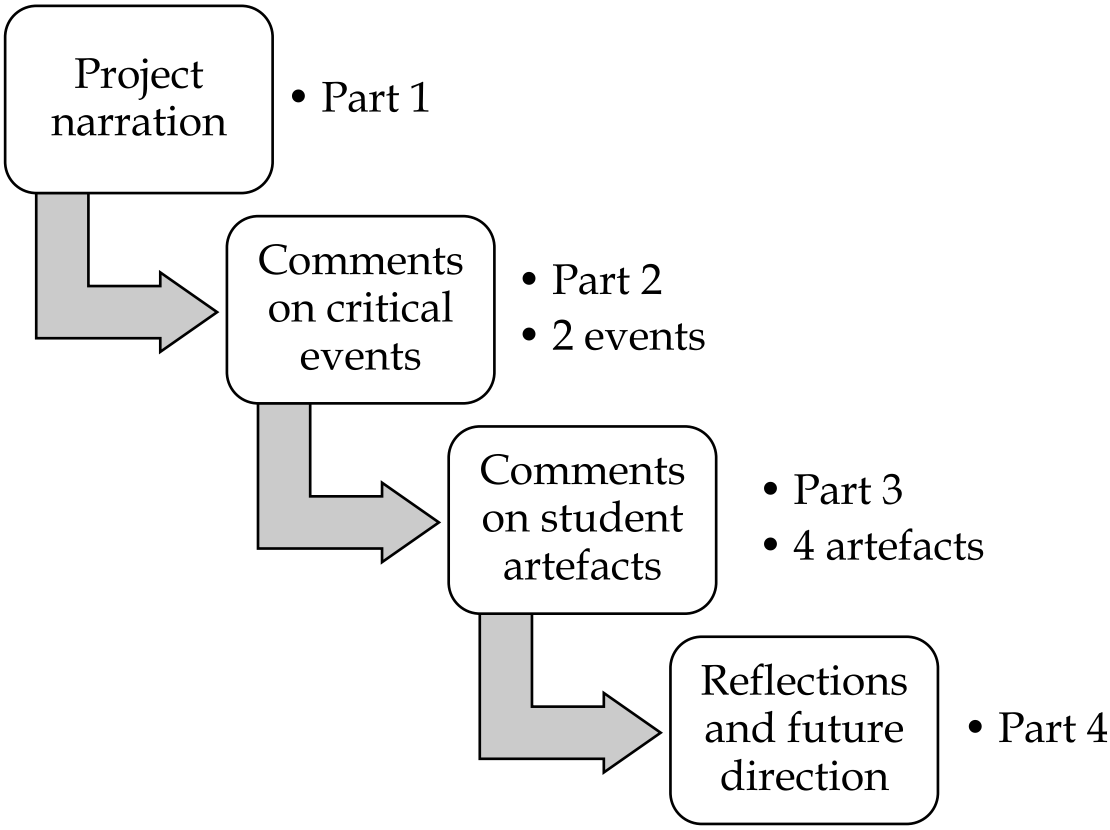


FIGURE 6 Structure of the post-interview

In the third part of the interview, the teacher was presented with a few pictures of student artefacts. The pictures of the artefacts included the project conducted by the student and their respective investigation forms. The teacher was not asked any specific question during this time, I allowed the teacher to take some time to go through the pictures and just comment on them. This was done to learn what the teacher's immediate reactions were to the students' work that was presented. The last part of the interview included two future prediction questions which were, 'If you had to do the same project again, how would you do it?' and 'How would you do projects in the future?' These questions were asked to learn what the teacher's learnings were during the projects. The interview ended with asking the teacher 'Do you think all content can be taught through projects?'. This was asked to learn what the teacher's opinions were after the experience of doing a project.

5.5.2 Classroom observations

The goal of the observation was to simply document and understand what was happening during the projects. I did not want to evaluate the teacher or the project in any way, therefore, I did not make use of a rubric that might have required me to judge the teacher's project implementation. However, I had read extensively about project-based learning and had an understanding of the components of PBSL, this helped me navigate the observation notes and the analysis of the same.

Although this is not an ethnographic study, I did borrow some practices from ethnography to plan my observations. Ethnographic observations provide an opportunity to understand a phenomenon in a holistic fashion (Kramer et al., 2019). To make a good observation plan, one must first make decisions about questions such as, 'What are the boundaries of my observations? What to observe? Should I focus on a particular aspect of project implementation or should I allow the focus to emerge as I observe?' (Kramer et al., 2019). The goal of my observations was to understand how the project was implemented and what happened during the project. Therefore, I recorded the teacher's actions and the resulting students' actions in the class sequentially. During group work, I dedicated my time to a single group throughout the class and noted down student talk and actions, as well as teacher's interaction with the group. Making notes this way gave me a detailed reference to what was happening in the project and how the project unfolded. I mostly took on the role of a silent observer, however, when the students were working on the projects in groups, I interacted with them by asking some questions about what they were doing. Discussions with the teacher during the breaks allowed me to better understand what was happening in the class, these discussions were also included in the observation notes.

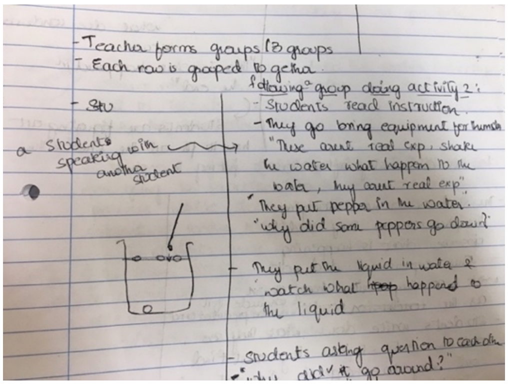


FIGURE 7 Example of observation notes (Week 1, WST)

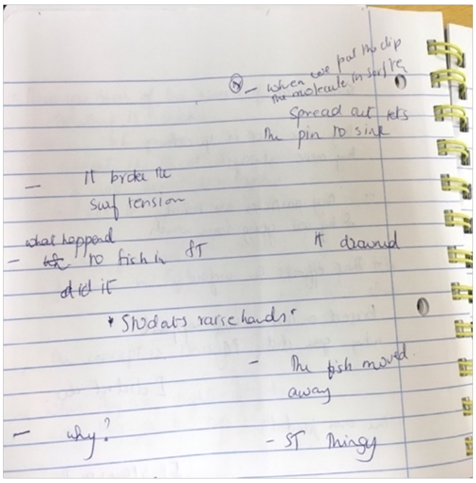


FIGURE 8 Example of observation notes (Week 3, WST)

Teacher	Student	Reflections/questions
The teacher starts the class by asking students about what they already know about circuits		
	Students are thinking what they know. One student answers "They are on computer boards"	
The teacher asks the students to think about what the circuits are related to. She tells the students to think about what they did in the previous ENS class.	A student answers Electricity	
The teacher says That's right		
Then the teacher goes on to tell the students that they must form groups. She tells the students that she will let the students form their own groups today. She first asks the students if they can manage making groups on their own	To this the students respond joyfully with a Yes. The students then start to ask the teacher questions related to forming the groups. They ask the teacher about the number of students in the group.	The class atmosphere in the beginning of today's class seems much quieter than usual. The teacher is very clear with her instructions of what she expects from the students. She waits until all student's pay attention before she starts to talk.
Then responds by saying "I'm letting you form the group, so if someone is left you should decide what to do"		
	The students start moving their chairs around to sit in a group. One student was walking around the class trying to search for a chair to sit on	
The teachers asks the student why he is walking around, then the teacher points at a chair nearby that had another students bag in it and asks the student to sit on that chair.	The students resisted a little bit and then sat in the chair.	
The teacher then explains to the students what they have to do in their groups. She says that the students have to go through the book and then figure out how to get the light bulb to switch on.		
Then she instructs the students that they have to come get the kits. The teacher then explains to the students	The students start to rush towards the kits.	

FIGURE 9 Example of typed notes

After the completion of each observation, I immediately typed the notes in a neat understandable format on a word document. I had to "decode" what was written and try to recollect all the incidents that happened in the class. As my observation notes were not always tidy (see e.g. FIGURE 7 & FIGURE 8), notes from each class required at least 3-4 hours of typing and organizing. FIGURE 9 illustrates what the typed notes looked like. The analysis of the observation notes already started at this stage in the form of reflective notes as represented in the third column of FIGURE 9.

Before ending this section, it is worth noting the reasons behind my choice for manual observations instead of video recording. First of all, project work usually involves a lot of group work during which students are not stationed in a single location. The class I observed had a practice where the students would go out of the classroom with a mat to sit on comfortably when they had to discuss in their groups. Video recording would not have allowed me to capture these group interactions. Second, the goal of this research was not to analyse the discourse in the class but to record the events that were unfolding. Observations and note-taking were deemed sufficient for this. However, like any other method, manual observations also come with its own disadvantages, these disadvantages and some steps taken to overcome them is discussed in section 7.4.

5.6 Data analysis

The analysis of a case study is said to be the least developed and the most difficult aspect of doing case studies, however, the analysis strategy developed needs to treat the data fairly to arrive at compelling analytic conclusions and rule out alternative findings (Yin, 1994). I began with the analysis by keeping these in mind. Creswell (2007) notes that the process of data collection, data analysis, and report writing are not distinct steps in the process, rather they are interrelated and happen simultaneously throughout the research process, this was also experienced during this research. The analysis for this research took place in four major steps as shown below.

Stage 1: Analysis of interview transcripts

Stage 2: Comparison of interview 1 and interview 2

Stage 3: Analysis of Observation notes

Stage 4: Comparison of findings from interview and observations

Stage 1: Analysis of interview transcripts

The analysis of the interview transcripts began with the goal of wanting to be able to draw comparisons between the pre-interview and the post-interview. After the initial steps of transcribing and reading through the transcriptions to familiarize myself with the transcripts, I started looking more closely at the data to plan my approach for analysis. A framework that best explains the steps taken in this stage of analysis is the interactive model for data analysis suggested by Miles and Huberman (1994) shown in FIGURE 10. The interactive model involves three steps that are performed simultaneously after the data collection, they are data reduction, data display, and drawing conclusions. I further explain below how I used these steps in my own data analysis.

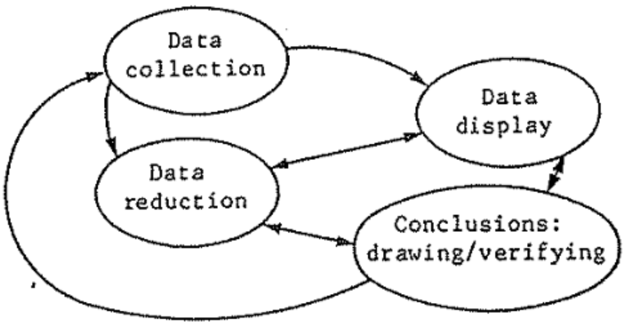


FIGURE 10 Interactive model for data analysis (Miles & Huberman, 1994, p. 12)

- Reduction

The reduction phase involved going through the transcription multiple times, removing pieces of data from there, and transferring them into cells on an excel sheet. After this stage, I had all the data from the transcription transferred to an excel sheet in the form of small pieces of data. An example of the reduction stage is shown in FIGURE 11 and FIGURE 12. At this point, I knew my data very thoroughly. As Miles and Huberman (1994) note, data reduction does not stop here, the reduction is part of the analysis process and the process continues until the end of the research.

Well, I find it, um.. I find that it was quite difficult to bring it all together, also to assess if they have learnt something. Some children were saying that "Oh I have no idea what this is about" and I was like "Oh dear, how don't you, you just finished exploring that" So it is hard to know what have they learnt so far and how much would they need support so, I think that's one of the most you know complicated things about project. Like how to set kind of the soft goals for the project and which are the check up situations or points where you would need to test their ideas or learning.

FIGURE 11 Interview transcript

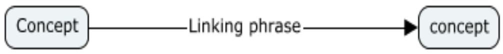
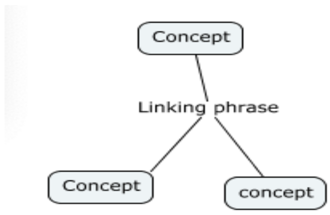
Question	Answer	Reference to thoughts or events during the project
your experiences like were during this project	Quite difficult to bring it all together	
	Difficult to assess if they have learnt something	
		"Oh I have no idea what this is about" and I was like "Oh dear, how don't you, you just finished exploring that"
	Hard to know what have they learnt so far	
	hard to know how much would they need support	
	how to set kind of the soft goals for the project	
	which are the check up situations	
	points where you would need to test their ideas or learning	

FIGURE 12 Reduced data

- Visual display of data

Tracy (2013) suggests the use of visual data displays in the form of a table, matrix, network, or a flowchart is not only a way of making sense of large amounts of qualitative data but it is also as a useful layer of analysing and thinking creatively about the data. Data displays organize data in a systematic format so that the researcher can make valid conclusions and perform necessary actions (Miles & Huberman, 1994). In this research, I used concept maps as a way of displaying the interview data. Using concept maps to display data allows for visual identification of themes and patterns and in turn facilitate the process of comparison (Daley, 2004). Concept maps not only helped me with reducing and displaying data but also in the analysis and comparison process. Concept maps of the transcriptions were drawn using a software tool called Cmap tools. The symbols used in the maps and their meanings are represented in TABLE 5. An example of a concept map is shown in FIGURE 13.

TABLE 5 Concept map symbols

Symbols	Meaning
	Represents the concept
	Links two concepts together
	Proposition: A logical connection of 2 concepts
	Cluster: A group of propositions

- Identification of clusters and assigning general codes to the clusters

After the concept maps were drawn, I identified clusters that represent the same concept. General codes were assigned to these clusters. The general codes are representative of what the cluster was about. The list of codes is represented in TABLE 6 and some examples of its respective clusters used for the comparative analysis are represented in TABLE 7. The reason for this approach to data analysis is that I wanted to interpret the data holistically without having to take apart the data too much by assigning too many codes.

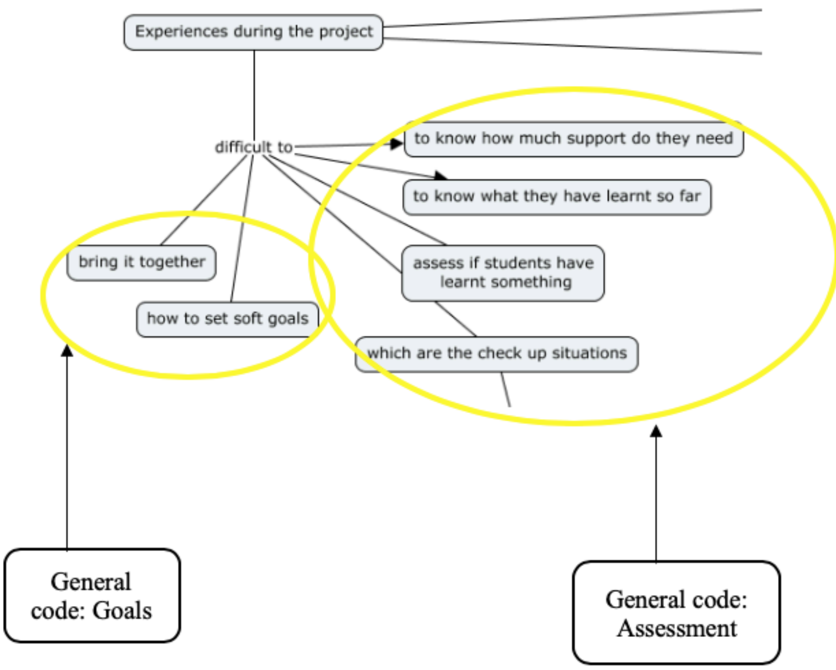


FIGURE 13 Concept map and clusters

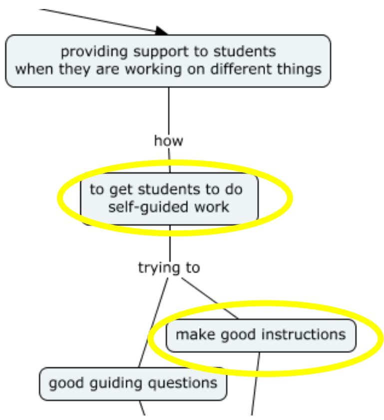
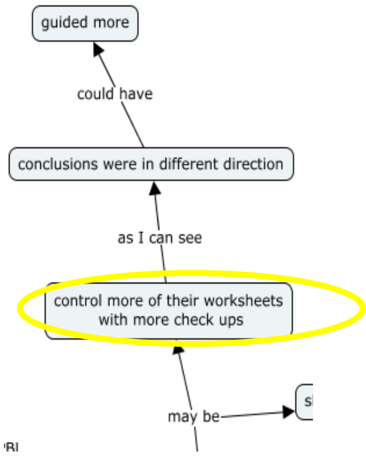
TABLE 6 General codes

General codes		
Descriptions of PBSL	Materials	Assessments
Group work	Talk about past experience	Goals
Difficulties	Teacher's role in PBSL	Reference to Finnish curriculum
Scientific method	self-guided learning	Science learning through projects

Stage 2: Comparison of interview 1 and interview 2

The comparison of interview transcripts began by first creating a word document by name 'comparative document'. A table was created like the one presented in TABLE 7. Clusters with the same general codes from both the interviews were placed next to each other for comparison. The similarities or differences in the way the teacher spoke about each of the codes was noted and a detailed description of the comparison was written down.

TABLE 7 Example of coding and comparisons

<table>
<tr><th>Codes</th><th>Interview 1</th><th>Interview 2</th></tr>
<tr><td>Materials</td><td>
</td><td>
</td></tr>
</table>

Stage 3: Analysis of Observation notes

The observation notes were analysed using the critical incident analysis technique. This method is used for many different purposes. Flanagan (1954) used critical incidents (CI) to study activity requirements in different professions. Thomson and Hall (2017) used this method to study schools. Tripp (2012) used CI to help teachers with reflection and learning. The critical incident analysis technique is flexible and can be adapted in many situations (Flanagan, 1954). This section explains what is meant by a CI, the purpose of using CI for this research, and how this technique was used in this research.

Powell et al. (2003) note that the events that are considered critical differs based on the research questions (RQ) pursued. This research seeks to understand how the teacher's conceptions relate to the implementation and how the teacher developed her conceptions of PBSL as a result of practical experience. Dilemmas, as seen earlier, stop teachers from implementing PBSL the way it was conceptualized, but they also act as learning opportunities for the teacher. These dilemmas reveal important insights that help in answering the RQs. Therefore, any incident that caused the teacher to encounter a dilemma is considered a CI. CI technique was best suited for analysing the observation notes for two reasons.

One, because of the type of data that was collected. The observation notes had recorded sequentially and in detail, the events that occurred in the class. Due to the availability of rich descriptions of the events, the data benefited most by identifying and analysing the CIs. Two, the implementation of PBSL was looked at from Windschitl's (2002) framework of dilemmas and therefore, rich interpretations could be drawn by analysing the dilemmas encountered. The analysis of the observation notes followed four steps. They are: 1) identifying the CIs 2) describing the CIs 3) forming categories 4) drawing interpretations. These steps are described below in detail.

- Identifying the CIs

As mentioned above CIs in this research represents the dilemmas encountered by the teacher during the project implementation. Some of these CIs were already identified during the observations and others were identified through multiple read-throughs of the notes. The observation data had a total of 10 CIs from the WST project and 25 CIs from the Electricity project. Each CI was given a number based on the sequence of its occurrence.

- Describing the CI

After examining each CI closely, a detailed reflection of the critical incidents was produced. The reflection included answers to questions such as What happened during the CI? How did this CI come to be? How did this incident impact the project? What could have been done differently? Discussions with the teacher played an important role in forming my understanding of the CIs.

- Forming categories

CIs that were related to a similar aspect/topic were categorized together. TABLE 8 provides a list of all categories along with an example of a CI under each category for the reader to have a glimpse of what the CIs under the categories looked like. An example of how one category named 'use of teaching materials' was formed is shown in TABLE 9.

TABLE 8 Categories

Category	CI	Description
Students readiness	CI 3	Students forget to follow the steps of the investigation
Time	CI 1	Setting up the class- teacher preparing for the project
Group work	CI 16	Students experiment with the equipment in the circuit construction kit in their groups
Unexpected results	CI 5	Paper clip sinks
Connecting science topics to students' real-life	CI 10	Teacher and students discuss the role of WST when washing clothes
Self-guided learning	CI 33	Student self-guided learning – testing if paper conducts electricity
Equipment in the school	CI 12	Printer does not work
Assessment in projects	CI 32	Teacher's concern about student learning – are they learning anything?
Teacher's content knowledge	CI 22	Teacher unable to answer students question on current
Use of teaching materials	CI 24	Students find it difficult to follow instructions on the booklet
Student absence	CI 9	Teacher spends time explaining the experiments again to students that were absent
Teacher learning	CI 8	Teacher change in instruction

TABLE 9 Formation of categories

Week	Number	Description	Category
Week 1	CI 4	Getting the students to write in the investigation form	Use of teaching materials
Week 4	CI 20	Teacher ensured students note down experiments in their notebooks	
Week 6	CI 24	Students find it difficult to follow instructions on the booklet	
Week 6	CI 25	Students filled booklets are being collected	
Week 6	CI 26	Students copy answers from each other	
Week 7	CI 28	Ensuring students fill the booklet	
Week 7	CI 31	Answers arrived at do not match answers in the booklet.	

- Drawing interpretations

In the last step, each category was looked at closely to interpret what the dilemmas involved tell about the project implementation. As mentioned before, Windschitl's (2002) framework of dilemmas was used as a frame of reference for the dilemmas identified in the observations. Therefore, the CIs under each category were seen in the light of this framework to understand what kind of dilemmas are present in the categories. For example, TABLE 9 represents the CI under the category named 'use of teaching materials'. This category reveals important insights into the use of teaching materials throughout the project.

Due to the limitation of space, a detailed description of the CIs is not provided in this thesis, however, these CIs will be referred to in the Findings section and a general description of them will be provided where necessary. How these critical incidents were used for analysis and interpretation is shown further with one example in section 6.3.

Stage 4: Comparing interview findings and observation notes

In the final step of the analysis, the findings from the interviews were compared with the findings from the observation. This was done by looking at how the general codes produced in the interview findings compared with the categories formed from the observation notes analysis. As an example, TABLE 7 and TABLE 9 can be compared with each other to provide important insights into the way materials were used in the projects. Further explanation about this comparison is provided in section 6.6.

5.7 Quality of the case study

Many case study researchers, based on their paradigmatic orientation, differ in the way they check for the quality of the case studies (Yazan, 2015). Yin holds a positivist orientation, as a result, his criteria look for objectivity and clear causal relationships in the data. Yin suggests four criteria to judge the quality of a case study, they are, construct validity, internal validity, external validity, and reliability (Yin, 1994). The tactics under each criterion offer clear guidelines to be followed to ensure and explain how the quality of the case study can be maintained throughout the research process. Since this study followed Yin's proposed methodology to conduct a case study, it makes logical sense to assess the quality of the case study using Yin's criteria. However, because this study takes on an interpretive paradigm, it acknowledges that Yin's criteria are not sufficient to assess the quality of the case study. An interpretive paradigm considers knowledge about reality to be mediated through the researcher, therefore, the researcher's past experiences and values inevitably influence how the study is conducted (Wahyuni, 2012; Tracy, 2013). To take into account and critically reflect upon the researcher's position and influence in the study, an additional criterion called 'self-reflexivity' is borrowed from Tracy's (2013) "Big tent" criteria to assess, improve and ensure the quality of the study.

Construct validity

Construct validity refers to the operational measure chosen to study a given concept, this refers to choosing the right source of evidence and the justification for it. This case study aimed at studying how one teacher's conceptions of PBSL relate to its implementation and how the teacher's conceptions of PBSL developed as a result of practical experience. For this, the study collected data from multiple sources and used the process of data triangulation to develop convergent lines of inquiry. Pre and post-interviews were used to understand the teacher's developing conceptions. Observations, student artefacts, and interviews were used to understand the relation between teacher's conception and implementation of PBSL. The study also maintained a chain of evidence throughout the data collection process by ensuring that all the data collected were clearly and immediately documented, examples of documenting the observation notes are presented in section 5.5.2. The study also makes explicit the connection between the questions, data, and the conclusions drawn, this can be seen in the way data is presented and interpretations are drawn in the findings section. By following these steps, the study was also able to maintain rigor during the data collection phase.

Internal validity

This criterion ensures that the causal relationship established in the research has taken into account all possible explanations. This case study used two theoretically driven propositions that guided the process of making sense of the data collected. The data analysis was approached iteratively and creatively where different steps such as concept maps, coding, categorizing and comparing different sources of data were used. This process not only increases the internal validity of the research but also increases the methodological significance of the study. Through this process, multiple explanations and interpretations were closely examined and compared with past research to build strong explanations about the causal relationships established between teacher's conceptions and implementations of PBSL, and between teacher pre and post conceptions of PBSL. This is elaborated further in the Findings section. In addition to that, constant discussions with my thesis supervisors and peers from the Master's program ensured alternative views and explanations were heard and taken into consideration.

External validity

External validity deals with the concerns of the generalizability of the case study findings. Case studies aim for analytical generalizations which connect the findings of the case study to a broader theory. The findings of this study were compared to the theoretically driven proposition to find out how the findings link with earlier studies related to PBSL in Finland and in general. This study also makes theoretically significant contributions to what is known about teachers' developing conceptions of PBSL in the context of teacher-initiated PBSL. By effectively comparing the findings of the study to various related factors such as teachers' education program in Finland, the use of teaching materials and the Finnish core curriculum for basic education, this study also makes practically significant recommendations that could potentially improve the way science is being taught through projects in Finland.

Reliability

Reliability refers to the steps taken to minimize errors and biases in a study. To achieve reliability in this study, every step of the process taken in the data collection and analysis process has been documented in detail, this is further explained in sections 5.5 and 5.6. A case study protocol was developed to guide the progress of the study. A case study database was maintained by ensuring that every evidence that was collected was stored in an easily accessible and understandable manner. Reliability can also be seen in the way the study provides a thick description of the projects and critical incidents that led to the findings.

Self-reflexivity

Self-reflexivity is referred to as an awareness of one's own identity, research approach, and an attitude of respect towards participants and audience of the study (Tracy, 2013). My choice of studying and understanding PBSL is influenced by my own experience as a student that did not enjoy school science and as a teacher that found it difficult to conduct meaningful projects. My understanding of the implementation of PBSL was also influenced by my experience in the Indian school context. This required me to be conscious of the contextual factors that influenced my understanding but were not relevant to the Finnish school context. As a teacher that has experienced teaching science through projects, I am aware that implementation of PBSL is not easy for the teacher due to many factors, this awareness influences my empathetic understanding of the teacher, this can also be seen in the way the teacher is presented in the study. Throughout the research process, I have maintained a reflexive stance by being open to and engaging in a constant dialogue between my understanding of the phenomenon, the data, literature, and the interpretations of the findings.

5.8 Ethical considerations

Ethical considerations for the study were taken into account in relation to the Finnish National Board on Research Integrity TENK's (2019) guidelines for ethical research. The privacy notice template provided by the university was used to inform the teacher about the purpose of the research, data collection, data storage, timeline, and participant's rights. This information was provided to the teacher in a clear, transparent, and concise way using simple language. The research proceeded after receiving signed consent from the teacher. This research did not require to collect any personal data from the teacher. However, a careful examination was carried out to identify and eliminate indirect identifiers, as a result, the anonymity of the teacher was maintained in the data. The data collected was stored in the U: of the university storage system as directed by the university's data protection guidelines. The data stored in the university system will be archived 6 months after publishing the research.

Permission to conduct the study was also received from the city's educational services. The principal of the school and the parents of the students were informed about my presence in the class. Since no personal data about the students was collected for the study, it was sufficient to simply inform parents about my presence, but parents were given the possibility to opt their child out of the observations. However, no parent expressed an objection. The students were informed about the reason for my presence before the start of the observations and were told to freely ask any questions if they wished to. Finally, the research will be shared with the teacher and the city's educational services.

6 FINDINGS

In this section, I present the findings of the study. By doing so, I answer the two research questions, RQ 1) How did the teacher's conceptions of PBSL relate to its implementation? and RQ 2) How did the teacher's conception of PBSL develop as a result of practical experience of doing projects? Each section represents a finding that resulted from comparing multiple sources of data in relation to the RQ. Excerpts from the interviews, observations and pictures from the projects are provided in order to better explain the findings.

Before proceeding with the findings, it is worth noting two points. One, with less than four years of teaching experience, the teacher in this study is fairly new to the teaching profession. This means that she is also quite new to the practice of PBSL. Two, this was the first time the teacher in this study was doing a project on a topic such as WST and electricity. In this sense, one can say that the teacher was brave enough to explore an area that she was new to, and by doing so, she was taking a big risk. The teacher's motivation and belief in PBSL as an efficient way of teaching and learning led her to try out these new types of projects and to be a part of this study in the first place. The teacher's journey with PBSL did not end here, she had planned on continuing with projects on water and electricity even in the spring semester in order to create a deeper understanding in students on these topics.

The typefaces used for the excerpts signify its source. The typefaces used are as follows, **Bold**: Pre-interview; *Italics*: Post-interview; Plain: observation

6.1 Conceptualization of PBSL

In this section, I present how the teacher conceptualized PBSL. It was seen that FNBE's (2016) recommendation for ENS education forms the basis of the teacher's conceptual understanding of PBSL. This is no surprise because the teacher recently graduated from the teacher education program and hence has had the opportunity to go through the new curriculum very thoroughly. Moreover, the aspects that the teacher associated with PBSL remained constant before and after the project implementation. FIGURE 14 represents the teacher's main conceptions of PBSL.

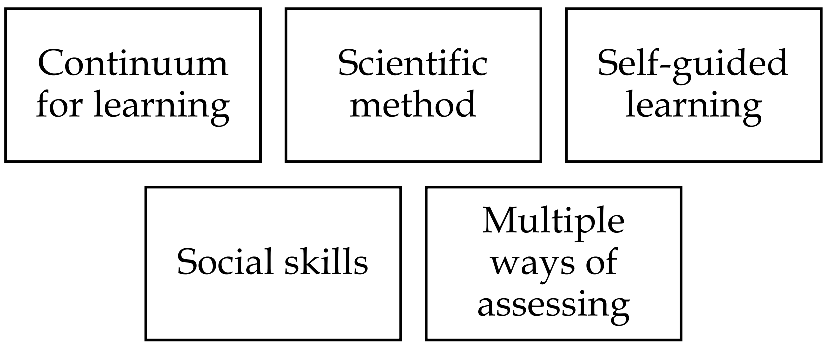


FIGURE 14 Teacher's conceptualization of PBSL

As mentioned earlier, FNBE's objectives of instruction and assessment criteria for ENS education in grades 3-6 has three categories: the first category is related to values and attitudes required for learning and responsible engagement in ENS, the second one is related to the working skills required for authentic learning and investigation in ENS and the third one is related to the knowledge and conceptual understanding required in various fields of ENS. As you will see, the teacher's conceptualization of PBSL closely relates to the second category which is about research and working skills. The excerpts offered below each paragraph are examples of the teacher explaining the aspects of PBSL in the pre and post-interview.

There was a very high focus placed on students engaging in the scientific method to learn science. That is, the teacher wanted the students to be able to develop surveys, observe the natural phenomenon, predict the results, note down the results, and make conclusions that explain the phenomenon. This was a major part of both the projects and was going to be a big part of ENS education for the whole academic year. How the scientific method was used in the project is presented in section 6.2.

> **I have started like scientific method like teaching them how to do survey for example like how to make observations and how to write them down and how to.. what kind of things are related when they are making those studies in classroom or surveys and I am teaching them and giving them the tools first and how to deduce and make conclusions as well based on their observations and cause yea I think that they have to be taught before, I'm gonna put them to investigate a topic and ask them to make observations.**

According to the teacher, having social goals related to group work and collaboration was one of the main aspects of doing projects. She saw collaboration as a way for students to develop shared knowledge and as an opportunity for students to practice how to express their thoughts and opinions.

> **I usually have some social goals related to each of the projects because they provide a great launch for all the social goals, and how to work in group. For example, how to negotiate with your peers, how to take responsibility for common work together.**
>
> *I think that my main goal is that they get to work in groups to share their like.. their own.. knowledge moreover like view of the thing and then they can build up their own understanding in groups when they are sharing their ideas together*

The teacher thought of projects as a way of creating bigger entities for learning by combining goals from different subjects. It was also seen as a way of creating multidisciplinary learning modules through which the students can make connections between different subjects while learning. However, the idea of creating a continuum was not spoken about by the teacher in the post-interview. Instead, the teacher shared her new learning of forming goals for projects, this is presented in section 6.3.

> **Ummm.. To me in short PBL is a process of learning bigger entities and it provides a continuum for learning due to its longer duration as well, so..**
>
> **Having projects and having continuums for different subjects and also how to combine them into bigger entities and how to create a multi disciplinary learning modules.**

Students being able to develop their own understanding of concepts through active participation was another important part of PBSL according to the teacher. She wanted the students to be able to independently form ideas about the phenomenon they are studying with little support from the teacher. This also closely relates to transversal competence, Thinking and Learning to learn (T1). The teacher encountered dilemmas as she attempted to engage students in self-guided work, this left the teacher pondering about questions related to this aspect after the project implementation. The role of the aspect of self-guided work in the projects is elaborated in section 6.5.

> **I think that one of the thing is that they are owning their learning process, during the projects. Like that's one of the main things and doing some individual work but also working with peers and like getting some skills for self-guided work as well**
>
> *I want to do things differently, so.. and I want the kids to try out and make mistakes and then kind of like ponder what did I do and why did something happen, I think it is quite important. You know part of the whole learning process. Have you owned the learning process yourself and you've been participating on it.*

The teacher thought of projects as an opportunity for students to showcase their skills and knowledge in multiple ways. She considered students' ability to offer and receive peer feedback and self-feedback as essential to learning through projects. Teacher's observation of the students' working process was also considered an important aspect of assessments. However, during the project, the teacher only used student artefacts and a pen and paper test for assessments. The role of assessments in PBSL and the dilemmas associated with it are discussed in section 6.7.

> **Ive always tried to create multiple ways of assessing and I also want them to assess themselves. I want them to assess their group. I want them to assess with their group as well and I want them to be able to give feedback to others so we have opponents for example in projects when they have presentations and we have opponents for checking the text what they have written about the projects**

Lastly, it is essential to note that the teacher's conceptualization of PBSL differs from the conceptualization of PBSL in this study in two important ways. One, the teacher did not consider the use of driving questions as central to the projects. Driving questions were used in the project, however, the questions were formed by the students and they were very systematic and specific to the experiment they were about the explore. Two, the teacher did not think of Projects as concluding with a tangible product. Projects according to the teacher were more inclined towards doing research projects rather than projects that end up with a tangible product. In conclusion, this finding summarizes the aspects of PBSL the teacher considered important both before and after the project. It also briefly describes how the teacher's conception of PBSL differs from the way PBSL is conceptualized in this research

6.2 Scientific method

This finding aims to present how the teacher conceptualized the scientific method for inquiry and how this was taught in the class. The teacher's conceptions of the scientific method of learning and the importance placed on it remained the same before and after the project implementation. During the scientific inquiry, the teacher wanted the students to observe a phenomenon, predict the results, note down results and arrive at a conclusion or reason for the phenomenon by discussing with peers. The teacher thought of the scientific inquiry (SI) process as a logical way of learning, this can be seen in the excerpt below from the post-interview.

> *I think its quite logical way of learning . Like first set a questions or a problem. Determine a problem. Like what kind of problem you have and then investigate like.. what is the reason for that.*

Investigation forms were used to help students learn the steps involved in a scientific inquiry. The investigation forms contained a series of steps that the students had to perform and note down. The steps in the investigation form for the WST project were as follows: Equipment, prediction, method, result and conclusion. On the first day of the WST project, the students were given three experiments related to WST. This was the first time the students were learning the science concepts through the scientific inquiry method. As the students were performing the experiment, they had to note down each step of the inquiry in the investigation form. However, when performing the experiment, the students forgot to note down the steps and forgot to perform the steps of the inquiry. The CI is presented in TABLE 10. Therefore, the teacher had to constantly remind the students to fill the form and perform the steps of the SI.

TABLE 10 Scientific inquiry

Week	CI	Description	Event
Week 1	CI 3	Students forget to follow the steps of investigation	The students finish performing the experiment, but they did not write down their observations, prediction and results on the investigation form

The teacher aimed at conducting a guided model for inquiry during which the students were to discuss in their groups to come up with a conclusion for the experiment they conducted. After this, all the groups shared their conclusions with the whole class and voted for the conclusion that best explains the phenomenon. On the last day of the project, the teacher used the help of videos to teach the concept of WST to the students. At this point, the scientific inquiry shifted from a guided inquiry model to a structured inquiry model, where the science concept was directly taught to the students after performing the experiment.

This finding draws attention to two points: One, using an investigation form did not automatically result in the students performing the scientific investigation process. As this was the first time the students engaged in an inquiry process to learn science concepts, the students needed to be reminded and guided to perform the steps of a scientific investigation constantly. Two, although the teacher began with a plan of using the guided model for inquiry, she was seen to shift to a structured model at the end of the inquiry process. During the structured inquiry, the students were given the explanation to the phenomenon observed. The findings presented further elaborates reasons for this and the dilemmas involved during the scientific inquiry process.

6.3 Future direction for PBSL

This section presents findings on the teacher's newly formed learning about goals in a project by comparing how the teacher spoke about planning for projects before and after the project implementation. In the pre-interview, the teacher stated that she starts planning for the projects by looking at the goals in the curriculum to check what the students need to know in different subjects, then she checks to see what goals can be combined together to form bigger entities. That is, the teacher wanted to create an integrated model for teaching different subjects through projects.

> **If I see that there are goals that would make a bigger entity and that could be done by working on projects, I will start making connections to the subjects that I am teaching and try to make a wholesome learning experience.**

Attempts to integrate different subjects such as language and history were observed, however, this was not seen throughout the project. Implementing the WST and electricity project resulted in the teacher to develop a new understanding of broad and narrow goals. The teacher's past experiences with projects have mostly been concerned with projects that have 'broad goals'. According to the teacher, broad goals are ones where there is no one right answer and these goals can be suitable for many subjects. Examples of such broad goals are social skills and scientific investigation. This was the first time the teacher was doing a project such as WST and electricity in which the students had to learn specific facts about WST, circuits, and electricity in order to come up with sound conclusions for the scientific investigation. The below two excerpts represents the teacher's description of broad and narrow goals.

> *Oh broader, like they would be more wider. For example if I would think about this goal that would be suitable for each subject would be that if the child is able to work with a pair or a group that's quite broad goal but then specific goals would be , I know that a circuit would need a source of energy it needs something to conduct electricity and you know so that would be quite narrow aspect.*

> *Usually when I have done some projects they have been .. um.. mixing those social skills for example. They've been learning about social skills and peer communication and they've had like bigger goals but this specific project has had like such like.. you know.. topics which have had quite narrow aspect on something. So its about circuit for example, there is just you know. Like of course exploring is a really good thing but may be like.. I should've just done the check ups for example to clarify already before the test like what happens.*

In order to elaborate this further, the teacher drew a comparison between the electricity project and a project on health habits which she had done previously. In the health habits project too, the students performed a scientific investigation where they made surveys, observations, and conclusions. However, the teacher thought that the health habits project, which had broad goals, was easier for the students as the topic of health habits was close to the students' life and their experiences, and therefore, they already have a deep understanding of the topic. Whereas, the electricity project, which has narrow goals, was hard for the students because the students do not usually have a deep understanding of specific aspects of the topic.

> *The conclusions are a little bit, something you can't tell before hand, harder to control may be. Because there is only one explanation. "This is the surface tension which is about the molecules getting together on top" "And this is the electricity and the current is flowing through because of this and this and this", so its kind of like yea.. I don't know, hard to explain.*

The teacher suggests the use of check-ups throughout the project to see if the students are going off-topic and to redirect them, however, she also mentions that there was not enough time during the project to do this. For the future, the teacher suggests that she will start the project by having the students go through some material related to the topic of the project so that the students have a preunderstanding of the topic even before the start of the project.

> *Next time when I'm teaching electricity , I would only may be give them time to get to know the material first, or may be we would explore first and then we would get to know the material and then the concepts would get deeper understanding and then we would go them through together with the some kind of base material but now they had to go through after exploring. They had to go through the material by themselves, because I thought that it would be good to do it afterwards to kind of like get better understanding of the theory.*

Another important point to consider in the light of this finding is that of teacher's content knowledge in the science concepts that were being taught. The health habits project was not only familiar to the students but also for the teacher, therefore, the teacher was perhaps able to accept a variety of conclusions from the students and was able to direct them flexibly. However, in the electricity project, the teacher's and the students' unfamiliarity with the topic led them to depend heavily on the teaching materials. They wanted to arrive at answers that were specified as correct in the teaching materials, therefore, there was no room for accepting a variety of conclusions and there was limited flexibility in directing student learning. This could have led to the understanding of the science projects as having narrow goals. The role of the teaching materials and teacher's content knowledge in the projects is further elaborated in section 6.6 and 6.7.

In summary, this finding shows that the teacher wanted to create integrated modules for projects, and while this was attempted during the project, it was not seen throughout the project. After the project implementation, the teacher thought of the WST and electricity projects as having narrow goals that required students to learn specific facts about the topics. The teacher's and students' unfamiliarity with the topic being taught was also seen to influence how this conception of goals was formed. For the future, the teacher plans on including more broad goals and introducing the science topics to the students before the start of the project so that the students have some familiarity with the topics.

6.4 Dealing with uncertainties

The teacher was seen to face some uncertainties during the project implementation, this finding explains how the teacher deals with the uncertain circumstance encountered in the WST project and how she, in turn, learns through this experience. The finding also highlights some of the challenges related to planning and preparation in PBSL.

One of the experiments in the WST project involved observing what happens when a paper clip is dropped in water. TABLE 11 represents the series of CIs that took place during this experiment. Analysis of them shows that the teacher's response to an uncertain circumstance acted as a learning moment for the teacher.

TABLE 11 Water surface tension project, Week 1

CI	Description	Events
		Teacher and the students are gathered around the paper clip experiment
CI 5	Paper clip sinks	Students try to make the paper clip float on water, but it kept sinking
CI 6	Teacher tries to make the experiment work	Teacher tries to make it float a couple of times too but does not succeed
CI 7	Students being critical about the experiment	Student says to the teacher "This is not an experiment, this is so boring"
		The teacher responds "Hey, if you have something rude to say, keep it to yourself. You don't have to say it like that"
CI 8	Change in instruction	The teacher asks the students to note down whatever they observed.
		The next group knew that the paper clip was supposed to float, They tried various tricks to make it float.
		One student got it to float, the students and the teacher are very happy.

In the CIs presented above two points are worth noting: 1) according to the teacher's plan, the clip was supposed to float on water, and in the future lessons, the teacher was going to use this to help students build an understanding of WST. However, the failed plan put the teacher in a position of uncertainty. A critical comment from the student added to the pressure the teacher was feeling. The teacher initially tries to make the clip float (CI 6). This act revealed the expected result to the students and the students aimed at arriving at that result instead of making a note of what was being observed. 2) the teacher is later seen to ask the students to note down what they observe (CI 8) and hence directing the students' attention back from the result of the experiment, to the process of observing and noting down what happened. But it is also important to note that this was not easy for the teacher, there was a moment of uncertainty before she made this shift. However, this moment of uncertainty can also be considered as a learning moment for the teacher where the teacher learns how to react in a situation where things do not go as planned in a SI.

After this incident, for the rest of the class, the teacher was seen trying to make the students do genuine observations. A scenario that depicts this was observed later during the class when a student in the pepper experiment calls out to the teacher and says, "*Teacher*, nothing happened", to this, the teacher responded, "That means you didn't observe". This shows that the teacher was placing a lot of importance on the act of observing.

When the teacher was asked to comment on her experience during this CI in the post-interview, she said that she should try out the experiments once before the students do it. However, it is important to note that when I walked into the class at 9:05, the teacher had just completed another class at 9:00. She spent the 5 minutes and some additional time during the class organizing the materials for the experiments. Since she is the class teacher, she also had to plan and manage her time among other subjects. In addition to that, PBSL requires a lot of planning and preparation from the teacher's side. The teacher also expressed that there is not enough time to prepare and plan for projects. In conclusion, through this finding, it was seen that PBSL involves scenarios, where the teacher is put in the position of uncertainty, however, implementing PBSL, is a process of learning for the teacher where she is seen to change or refocuses her action to enable the students to engage is SIs.

6.5 Self-guided work in PBSL

Ensuring that students engage in self-guided work during PBSL was one of the aspects the teacher considered important. The teacher actively attempted to ensure that the students developed a correct understanding of WST and electricity with little help from the teacher. However, this was not a simple task. Even after the project implementation, the teacher was seen to ponder over how to find the balance between having the student form understanding of the topics by themselves and providing them enough support to be able to form a valid understanding of a topic. This finding also offers an insight into the nature of learning when students engage in self-guided work.

First of all, by self-guided work, the teacher means that students should be able to learn new information by exploring multiple sources of data, by making connections, by reasoning, and by learning from and with peers. She saw herself as a guide that would direct the students in the right direction, but not as one that would provide information to the students. She wanted the students to take responsibility for their learning and progress. She also considers self-guided learning as the students' ability to be able to form an understanding of topics in different ways that the teacher might not have imagined.

This understanding of self-guided learning is in line with the FNBE's definition of transversal skill 'Thinking and learning to learn' (TI). T1 encourages students to construct knowledge in multiple ways and to engage in creative explorations. Teachers' are encouraged to guide students to use information independently and with peers for problem-solving, argumentation, reasoning, drawing conclusions, and inventions. The below excerpt from the pre-interview shows how the teacher views self-guided work as well as the value she places on students' independent learning.

> **They have to be more self-guided when they are doing projects, they cannot be dependable on the information given by the teacher. Well it's not teacher led anymore. I am not making sure with questions did they understand something. They have to take responsibility more about their own learning and like.. about their own progress as well.**

Before the project implementation the teacher also addresses some challenges associated with self-guided work, she mentions that it is a challenge to get all students to participate equally and to ensure that all students are engaged in their learning.

> **But the problem is how to get everyone to participate equally and also how to engage them in learning so then you know when it is not teacher led anymore. When I am not there to help them out in every step.**

The electricity project was designed in such a way that the students had to find new information and form new understanding by themselves with the help of the materials that were provided. It was observed that when the students engage in self-guided work, there are possibilities that the students may not develop clear or valid conclusions of the topic. In the post-interview, the teacher spoke about the difficulty in knowing what the students have learned and how much support would the students need when doing self-guided work. The teacher recognizes that to be able to ensure that the students do develop a valid understanding of the topic, it is necessary to have regular check-ups and to offer timely support and advice to the students. However, in this project, the teacher did not have enough time to do so.

> *I think that it is crucial that I make sure that they have also got the point of the thing. But not the way that I would be just guiding or taking their learning, only in the way that I want it to be. I want them to you know to be able to learn something that I have not imagined. I might not be thinking outside the box sometimes so my view of the thing is not the only truth. But Still I need to have some check-up points. Do you know what I mean?*

An example of students forming their understanding of conduction and the explanations they give for the phenomenon is presented below. On this day, the students were checking if materials such as paper, aluminium foil, straw, and other such materials conduct electricity. One group of students was checking if the paper conducts electricity. TABLE 12 shows the student activities during this experiment. FIGURE 15 shows the picture of students checking if paper conducts electricity.

TABLE 12 Electricity project, week 7

CI	Description	Event
CI 33	Student self-guided learning – testing if paper conducts electricity	Students build a circuit with a paper in it. Students notice that the bulb does not light up when the paper is used in the circuit Students connect two ends of the wire while the paper is still part of the circuit Students note this down in the conclusion section

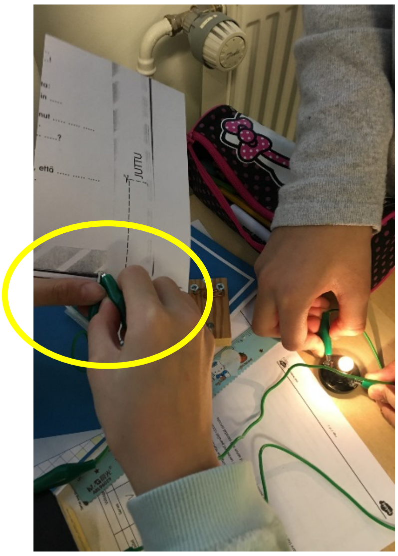


FIGURE 15 Testing if paper conducts electricity

> In the results part of the investigation form, the students wrote: "Paper cannot be a conductor unless you put one of the end of the wire to another"

Here it can be seen that the students understood that paper is not a conductor. They also recognize that for a circuit to function normally, the wires need to be in contact with each other. However, it is unclear why they still wanted the paper to be part of the circuit while it had no role to play in making the circuit function. The below excerpt is the teacher's comment on this investigation. She says that some feedback at this point would have helped the students get a clearer idea of the investigation.

> *I don't know why they have written this "Unless you put one of the wires to another" cause the paper has nothing to do with that. I don't know if they're trying to make explanations you know, somehow. May be at this point now I can see that. May be at this point. I should have gone them through really carefully and then give them individual feedback.*

The teacher further explains that although the conclusion offered by the students is not very clear, it is not exactly incorrect either. This is because, one, it is clear that the student understood the concept of conduction, and two, it tells us about how the students are beginning to form their understanding of the concept. The below comment by the teacher highlights the nature of self-guided work in PBSL. Although the goal is to have the students understand the concepts through exploration, they do not need to get the concept correct in the first go, the students are supposed to learn through continued exploration. Therefore, PBSL is a process of learning and does not end with one or two projects. The below excerpt shows how the teacher thinks about student learning.

> *But one thing I am pleased with is that they have actually written a conclusion cause they have like this is the.. they have given like something which tells about their thinking process and even though it is not correct scientifically or based on the theory then still it's a concept of what that person has about that topic in that point so.. it's not you know incorrect. Cause they can still develop their ideas of the whole topic.*

In conclusion, this finding shows that the teacher placed importance on self-guided work throughout the project. However, the challenges she associates with self-guided work changes after the project implementation. The teacher faces a dilemma in not knowing if and what the students are learning through the self-guided work. It also raises questions about how much support needs to be given and what kind of support needs to be given to the students during self-guided work. This finding also tells us that when the students are engaging in self-guided work, they may not develop a clear understanding of concepts in the very beginning. However, PBSL is a process through which students develop their ideas. Therefore, in PBSL students must engage in learning about topics for an extended period.

6.6 Changing roles of teaching materials

The teacher relied on materials as a tool that would help with the implementation of projects. The materials used in this project were all taken from an online teachers' resource marketplace, some were just investigation forms and some were exercises that helped students learn new information about the topic. The materials that initially had the purpose of being a tool that helps students with self-guided work became the goal of the project and this, in turn, shifted the focus of learning from exploring the activities to having to fill out the forms. Eventually, the material was seen as the means that would inform the teacher about student progress. The three pieces of data presented below depict how the role of materials changed throughout the project.

As mentioned in section 6.1, in the pre-interview, the teacher considered 'students owning their process of learning' and 'students engaging in self-guided work' as important features of project work. To achieve this, the teacher planned on using good guiding questions and materials that would assist students in self-guided work. Therefore, materials were seen as a tool that would help the students with self-guided work. This can be seen in the below excerpt from the pre-interview.

> **I have to plan a lot and do a lot of extra to prepare them for the self-guided work. I can't be with them all the time, that's why I need lots of guiding questions and material.**

TABLE 13 shows the CIs from week 6 of the project. During this week students were taken to the computer lab to construct parallel and series circuits on the Circuit construction kit DC (CCDC) application. The CIs represent the role of teaching materials during the project.

TABLE 13 Electricity Project, Week 6

CI	Description	Events
		Students start by constructing normal circuits. Then the students experiment with all the tools that were available in the application and started to use them. The teacher redirects the students to focus on constructing the parallel and series circuits as instructed in the booklet.
CI 24	Students find it difficult to follow instructions on the booklet	Students were not able to follow the instructions so teacher goes around the class explaining what they needed to do Some students had completed the activity, but some students were still trying to figure out how and what to do
CI 25	Students filled booklets are collected	Teacher checks if students have filled the booklet and collects the booklets from students before they leave the class
CI 26	Students copy answers from each other	the students who forgot to fill in the table during the activity started to copy findings from their friends and finally submitted the booklet.

As one can notice, the emphasis placed on having students fill in their booklets in CI 25 led the students to copy the answers from their friends in CI 26. Therefore, filling out the booklet became the goal of the activity during the projects. Another point to notice is that the students found it difficult to follow the instructions provided in the booklet, this was also recognized by the teacher during the project as well as in the post-interview.

In the interview 2 when the teacher was asked, 'If you were to do the project again, how would you approach it?' it can be seen that in addition to wanting to do shorter projects, the teacher talks about controlling the students' worksheet by having more check-ups. The teacher thought that the conclusions made by the students were in different directions. Therefore, she says, if she had checked their materials more during the project, she could have guided the students in the right direction. At this point, worksheets/materials are seen as a tool that would inform the teacher about the students' learning progress.

I would may be control more of their worksheets for example, I would check up, check what kind of results they have got. I don't know maybe I would do shorter process overall, because I have not had resources to look up all the material they produce all the time. I am now as I can see some of the conclusions were totally going into different directions, may be that time I could have guided more to those people.

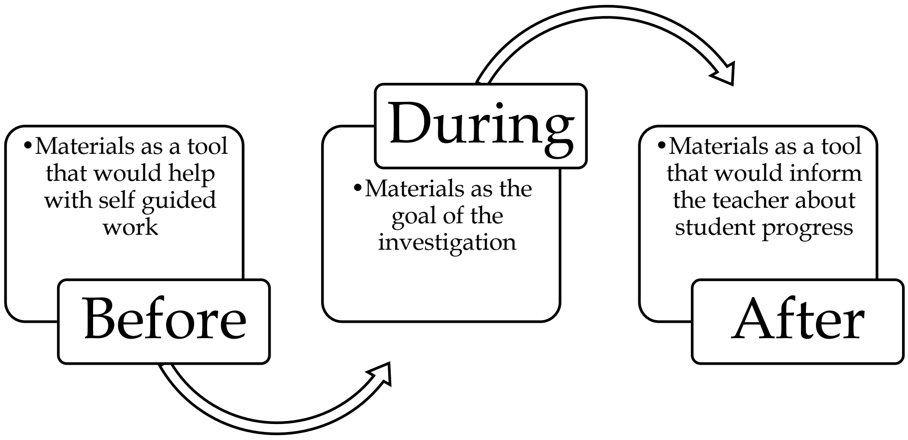


FIGURE 16 Role of materials

This finding also highlights issues related to materials and these issues are crucial to be considered. First, the teacher needs to find materials for each project by herself. This process is not only time consuming, but it is also hard to find materials that are appropriate for the specific goals of each class. An even more important issue that needs to be addressed is that internet sources for materials may not always be reliable or of good quality and this severely affects the quality of student learning through PBSL.

In conclusion, through this finding, it was seen that the role of teaching materials transformed throughout the project as shown in FIGURE 16. This brings an interesting perspective on the use of materials in projects. Teachers need to be cautious about the kind of role materials take when learning science through projects and decide how dependent should students be on the teaching materials when performing scientific investigations. This finding also opens up a space to ask questions such as 'what is the purpose of using materials in PBSL' and 'How can materials be used so that it supports student learning efficiently?'

6.7 Assessments in PBSL

This finding reveals how the teacher conceptualized assessments in the pre-interview and some challenges associated with assessments during the project implementation. In the pre-interview, when the teacher was asked about how she uses assessments in PBSL, she talks about using multiple forms of assessments such as peer feedback, student observations, and the project itself as an assessment. However, during the WST and electricity project, there was no evidence of the teacher incorporating these forms of assessment. Instead, the teacher had prepared a final assessment for the students on the last day of the project. In this assessment, the students had to do all the activities they had done during the project again. In the post-interview, the teacher mentioned that the observation of students' group working skills and their working process would be considered when giving feedback for students at a later point. The below excerpt shows comments on the use of assessments in the pre-interview.

> **I've always tried to create multiple ways of assessing and I also want them to assess themselves. I want them to assess their group. I want them to assess with their group as well and I want them to be able to give feedback to others so we have opponents for example in projects when they have presentations and we have opponents for checking the text what they have written about the projects, so I'm using multiple ways, but Im also.. at the end of the project I gave everyone feedback, written feedback.**

After the project implementation, the teacher shares about the difficulty in knowing how much support the students needed and when to have the check-up points to understand what and how much the students are learning during the projects. The teacher also shared this concern in one of our informal discussions during the break time. The below excerpts from the post-interview further explain this dilemma.

> *Some children were saying that "Oh I have no idea what this is about" and I was like "Oh dear, how don't you, you just finished exploring that" So it is hard to know what have they learnt so far and how much would they need support so, I think that's one of the most you know complicated things about project.*
>
> *which are the check up situations or points where you would need to test their ideas or learning. And.. so that's why I had those lessons where I try to make the concept clearer when I was doing it at the front of the class and in front of the class with the circuit construct and then we investigated that a bit more as well, later on together.*

This difficulty in knowing what the students had learned led the teacher to conduct a whole class lesson where she went through the science concepts with the students. A detailed account of that class is presented below in the next section. In conclusion, this finding shows that the teacher wanted to use multiple ways of assessing students. However, in the projects, there was no visible use of multiple assessment strategies. The teacher found it hard to know when to assess students and to know how much support they needed. The lack of time also limited the teacher from performing other forms of assessments during the projects. In the end, the teacher conducted a pen and paper test to assess students' learning by testing them on all topics they learned during the projects.

6.8 Teacher's content knowledge

The dilemma of not knowing if and what the students have learned in the series and parallel circuits topic led the teacher to conduct a whole class teaching to clarify doubts and to take the learning process forward. However, during this whole class teaching the teacher was seen to encounter circumstances where there were some difficulties with the teaching materials and the CCDC application. The teacher's lack of familiarity with the topic and the application used also had a role to play in causing these difficulties. Therefore, this finding throws light on the importance of teacher's content knowledge in PBSL.

The CIs in TABLE 14 show the series of events that took place during the whole class teaching. The class began by the teacher going through the difference between parallel and series circuits. Then, with the help of a video, the teacher explained the concept of voltage and current. After this, the teacher with the help of another student started to construct series and parallel circuits in the CCDC application to show the students how to measure voltage and current, this was displayed on the white screen.

TABLE 14 Electricity project, Week 7

CI	Description	Events
		As the teacher constructs the circuits, students are asked to write down the readings.
CI 28	Ensuring students fill the booklet	Teacher goes around the class to check if everyone is writing down the readings
		The student continues adding bulbs to the circuit in series and parallel and to measure the voltage and current
		To check the current in the circuit, the student connects the ammeter. The battery gets set on fire.
CI 29	Learning how to use the CCDC application	The teacher and the students figure out that the ammeter needs to be connected in series with the component in the circuit
		After filling out all the values in the table, they went through the questions provided in the booklet.
CI 31	Answers arrived at don’t match answers in the booklet	The teacher notices that the answers provided in the booklet were different from the answers they arrived at
		The teacher tries to construct the circuit again, but the battery gets set on fire again
		It was now almost time for break, so the students go out for the break.

During the break, the teacher and I were discussing the answers to the questions in the booklet and were trying to figure out what went wrong. All the instructions provided in the booklet were followed, yet the answers arrived at were wrong. The teacher shared with me that doing projects requires the teacher to stay on top of all topics and content and be able to solve such unpredictable incidents but this is hard to achieve.

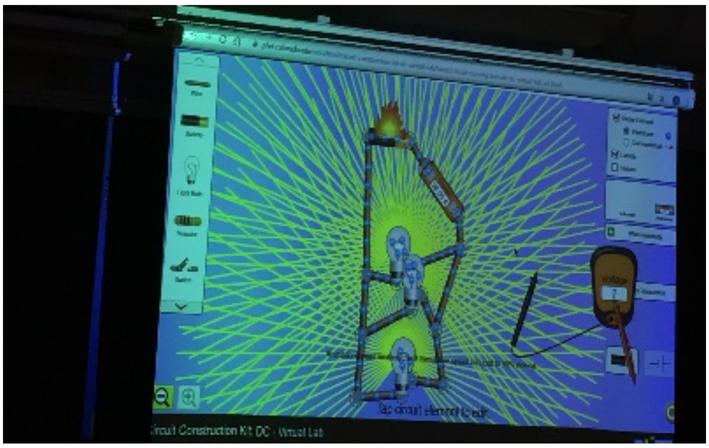


FIGURE 17 CCDC whole class teaching

FIGURE 17 shows an example of the circuit construction projected on the screen. Three very important points stand out as important in the CIs presented above. One, using the online CCDC needed some practice. Two, the teaching materials that were used for this activity were not appropriate for the students. Three, the teacher was unfamiliar with the topic being taught. CCDC was a new application for both the teacher and the students, this means that they needed to get used to learning how to use the tools provided to make circuits and measurements. In the beginning, the students spent much time trying to figure out how to use the tools. The tools provided in CCDC had various options. For example, the students were able to change the voltage in the batteries and the resistance on the bulbs. Doing so impacted the values read by the ammeter and voltmeter, this was one of the causes for the wrong conclusions.

The booklet that was used was not only difficult for the students to follow but it was also restrictive as the students had to follow the steps mentioned in the booklet and could not deviate from it too much. Over-reliance on the teaching material was seen to impact the purpose of investigation in projects negatively. However, the teacher's unfamiliarity with the topic and importance placed on self-guided learning led to this over-reliance on the materials.

In the post-interview, the teacher also shared that this is her first time using the CCDC tool. Therefore, it was difficult for her to teach using this tool while she was building her knowledge about it. However, she considered the whole group teaching as necessary because it played a dual role in taking the learning process forward. One, it allowed the students to confirm what they have been doing with the circuits. Two, it offered the teacher an opportunity to gauge the students' understanding by asking them questions as they went through the booklet together. The below excerpt is the teacher's comment on her experience of the events represented in TABLE 14.

> *I felt a bit like unsure of course because I had not been using it and also to get into that situation where you don't master all things that you know are happening.*

The teacher also acknowledges that the booklet used to investigate parallel and series circuits was hard for the students to follow and therefore there was a need to go through it together with them to get a shared knowledge of the concept. She thought of it as a situation that both the teacher and students were in together, figuring out how to solve the questions.

> *I could test also do they know what to do next like "what shall we do after I set the battery here" so that was also the testing point. But I felt that uh.. the form that I had uh.. like that was a bit complicated for children to understand how to fill it our so we had to go through it together. So I think that these took the process of learning forward, we needed that to get the shared knowledge.*

In conclusion, this finding points to the importance of teacher's familiarity with the tools used and the topic being learned through projects. This finding also shows that teachers have to be careful about the appropriateness and quality of the materials used during projects.

7 DISCUSSION

This study aimed to understand the teacher's conceptions and its influence on the implementation of PBSL when projects are initiated by the teachers. The study relied on two main theoretical propositions, which are: Teachers' conceptions of PBSL influences how PBSL is implemented, and Teachers' conceptions of PBSL develop as a result of practical experience. The research questions (RQ) that guided this research are RQ 1) How did the teacher's conceptions of PBSL relate to the implementation? RQ 2) How did the teacher's conceptions of PBSL develop as a result of practical experience of doing projects? This section discusses how the study answered the RQs and how the findings add value to what is already known about teachers' conceptions and implementation of PBSL in general and in the context of the Finnish elementary school system.

This case study is unique and offers interesting insights to understand teacher-initiated PBSL because, one, the teacher in the case study is new to the teaching profession, and two, this was the first time the teacher embarked on a journey to teach science concepts such as WST and electricity using projects. As was seen earlier, FNBE's recommendations for ENS and the teacher's past experiences with PBSL formed the basis for the teacher's conceptions of PBSL. The teacher conceptualized PBSL as having 5 aspects, which are: 1) PBSL offers a continuum for learning 2) students learn the scientific method of investigation through PBSL 3) students engage in self-guided learning 4) PBSL offers a launch for social skills 5) PBSL offers multiple ways for students to represent learning.

Scientific investigations, building social skills, and self-guided learning was implemented persistently. Using projects as a continuum for learning was observed sometimes. There was no evidence of projects being used as a way for students to represent learning in multiple ways. While the teacher attempted to implement PBSL according to her conceptions, many factors played a role in how the projects were implemented. The dilemmas faced along the way resulted in the teacher developing new conceptions about PBSL implementation. This supports previous research that implementation of PBSL results in teachers developing new learning about future implementations of PBSL (Ladewski et al., 1994; Marx et al, 1994; Windschitl, 2002; Tal et al., 2006; Dole et al., 2016). The discussion of the findings is organized into three sections, namely, 1) Conceptualizations 2) Conceptions in relation to implementation 3) Developing conceptions.

7.1 Conceptualization

The first section discusses how the teacher's conceptualization of PBSL compares with the way PBSL is conceptualized in this research.

- Driving questions

The teacher's conceptualization of PBSL differs from the way PBSL is conceptualized in this research in two important ways. First, a driving question was not considered essential to the projects. A driving question in PBSL is what differentiates PBSL from hands-on activities and experiments, it creates a need to learn by meaningfully connecting content knowledge to students' real-life (Capraro et al., 2013; Krajcik & Czerniak, 2018). Through the WST and electricity projects, the students were not on a quest to answer a big question or solve a problem. Developing good driving questions requires the teacher to view the curriculum as a dynamic set of ideas that integrates different subject areas (Marx et al., 1994). According to Tahvanainen et al. (2019), class teachers in Finland see integrative teaching as a familiar method and as a method that inspires them to teach. In line with this finding, the teacher in this study also described projects as an opportunity to combine goals from different subject areas to form a continuum for learning. Attempts to integrate subjects, like history and language was observed during the project. However, there was not a heavy emphasis on this aspect, and the lack of a driving question, or a bigger purpose of exploration led to the projects remaining as individual science lessons with some activities and investigations.

Although the teacher's conceptualizations of PBSL are in line with FNBE's objectives and assessment criteria for ENS, it mostly aligns with the second category which is to develop students' research and working skills. The other two categories essentially place importance on connecting science to nature, student surroundings and community, and sustainable development (FNBE, 2016). Perhaps, giving importance to the other two categories would have led to developing a driving question or problem that may have generated the possibility for more genuine explorations.

However, new teachers were seen to take up to two years with constant support to develop driving questions that link science concepts to students' life in a meaningful way (Rogers et al., 2010). Even the teachers that were provided with a pre-packaged project and driving question were seen to require time to create genuine explorations through the driving question (Cook & Weaver 2015; Mentzer et al., 2017). Connecting science learning to the students' life in an interesting and meaningful way is not an easy task and requires a lot of practice. The teacher also reflected upon the fact that it was hard to connect the science topics to students' real-life. This is in line with one of the findings from the survey research on phenomenon-based project learning in Finland where teachers identified the need for ideas to teach using this approach (Tahvanainen et al., 2019).

- Artefacts

The second way the teacher conceptions of PBSL differs from the way PBSL is conceptualized in this research is that the teacher did not mention creating artefacts as essential for PBSL. The teacher saw projects as research projects in which students would explore a phenomenon and build an understanding of it in their groups and by themselves. This is not surprising as the teacher's conceptions of PBSL is mainly informed by FNBE's recommendations, and the curriculum does not explicitly mention that projects or inquiry science need to end with the creation of artefacts. However, the creation of artefacts creates an avenue for students to display learning in multiple ways, it is an important form of assessment in projects (Blumenfeld et al., 1991). Artefacts do not necessarily have to be a physical product, it could be any form of representation (Larmer et al., 2015). After the project implementation, the teacher considered students' worksheets as artefacts that inform her about students' learning.

7.2 Conceptions in relation to implementation

This section discusses three important aspects that stand out when looking at teacher's conceptions in relation to the implementation of PBSL. They are how scientific inquiry was used in projects, the role of teacher's content and PCK and how students were assessed during the projects.

- Scientific inquiry

Scientific inquiry had a very important place in the teacher's conception of PBSL. PBSL is not only new for the teachers but also new for the students and students need to learn how to learn in a project setting (Windschitl, 2002; Ertmer & Simons, 2006; Rogers et al., 2010). As this was the first time the students were constructing science knowledge through scientific inquiry process, the students needed to be constantly reminded about having to follow the steps of scientific investigation. Students' competence is stated as a common challenge during the implementation of PBSL (Han et al., 2015; Tahvanainen et al., 2019). However, it is seen that for students to get used to learning through PBSL and for it to affect their learning, it needs to be implemented consistently for a long period (Erdogan et al., 2016).

- Content knowledge

The scientific inquiry model used in the WST project transformed from a guided inquiry model to a structured inquiry model. Students that learned science through a guided inquiry model were seen to better develop their science content and process skills when compared to those that learned through a structured inquiry model (Bunterm et al., 2014). To guide students to construct knowledge in constructive pedagogies such as PBSL requires teachers to be able to scaffold learning through questions and discussions (Kokotsaki et al., 2016). A research conducted to study how pre-service teachers in Finland ask questions during observation revealed that they needed more practice to form questions that can guide students' knowledge construction in science (Ahtee et al., 2011). Teachers' understanding of science content is seen to play a very important role in this aspect, teachers with strong content knowledge were seen to be able to direct students' knowledge construction efficiently (Marx et al., 1994; Richardson, 2003; Tal et al., 2006; Kokotsaki et al., 2016).

In Finland, it is hard to expect class teachers in grades 1-6 to be experts in science subject teaching as they are not specifically trained for it. During the class teacher training, pre-service teachers are free to choose 60 credits of subject studies (this is different for different universities), and science is not the most popular choice among pre-service class teachers (Evagorou et al., 2015). The subject studies in science during the teacher preparation programs mainly focus on pedagogical knowledge and not the content knowledge of science (Lavonen & Juuti, 2016). In their survey research of Finnish teachers practicing PBL, Aksela and Haatainen (2019) identify the need to improve Finnish teachers' pedagogical content knowledge (PCK) in PBSL. In line with their suggestion, this research also points towards the need for further support to develop primary class teachers' content knowledge as well as PCK in science.

- Assessments

Although the teacher considered the use of multiple ways of assessing as an essential aspect of PBSL, a pen and paper test was conducted at the end of the project. During this assessment, the students had to redo the investigations they had performed in the conduction experiment. The goal of this test was to see how well students were able to perform each step of the investigation process. FNBE's (2016) assessment criteria under research and working skills for ENS education also specifies the need to assess students' skills in specific steps of the scientific investigation process. However, it is important to note that the purpose of doing the scientific investigation is for students to take on the role of a scientist to wonder, ask questions, observe, develop explanations and conclusions based on data, just like a scientist would in real-life (Krajcik & Czerniak, 2018). Formally testing this investigation process reduces the purpose of doing scientific investigations to a bunch of steps that need to be followed and in turn, limits students from engaging in genuine scientific investigations. Beginning 7th-grade students in Finland were seen to hold only naïve or mixed understanding of scientific investigations although the scientific investigation is given much importance in the curriculum for grades 1 to 6 (Lederman et al, 2019). The current study sheds light on a possible reason for this finding.

7.3 Developing conceptions

This section discusses the teacher's developing conceptions of PBSL as a result of practical experiences. The section is divided into three parts, they are: Teaching materials, New conceptions of goals in PBSL and nature of learning through project implementation.

- Teaching materials

The teacher in this study saw teaching materials as a tool that would support students' self-guided scientific investigations. Teaching materials are seen to play an important role in students developing an understanding of science concepts (Rivet & Karjcik, 2004). Students' learning through projects develops over time and the curriculum materials must be coherent to support students in such knowledge construction (Miller & Karjcik, 2019). The teacher in this study used materials from an online teaching resources marketplace. Borrowing externally developed materials requires the teacher to be able to adapt the materials to his/her classroom. Teachers' experience with using externally developed materials and the teachers' understanding of the science concepts was seen to play a huge role in how well they adapt the materials to the classroom (Fogleman et al., 2011). Dilemmas were encountered during the project as the materials used were not appropriate for the students' level.

The teacher later pointed out the challenge of finding materials that align with the Finnish curriculum and her classroom, and of the unavailability of time to make materials by herself for the class. This is also seen in previous research with Finnish pre-service and in-service teachers as they pointed out the lack of time for planning projects (Aksela & Haatainen, 2019) and challenges in developing materials for Project learning by themselves and wished for the availability of ready to use materials (Lindell et al., 2018). Finally, the discussion on teaching materials raises an important question about the quality of teaching materials online. An analysis of the most downloaded online teaching resources available on teachers' marketplaces revealed that these materials were of low quality as they lacked clarity and instructional guidance. They were not cognitively demanding and did not sufficiently support students' cognitive development (Polikoff & Dean, 2019), and as seen here in this study the teaching materials used did not sufficiently support the student or teacher's development. Therefore, the quality of online teaching materials cannot be taken for granted, and teachers need to be critical about the use of these materials.

- New conception of goals in PBSL

The teacher explains her new conceptions of narrow and broad goals by comparing her current experience with her prior experience of doing projects. It is interesting and important to note here that the teacher linked the challenge of ensuring self-guided work in these projects to the topic of the project. She thought that self-guided work in WST and electricity projects was hard because of the nature of the topic. However, this discussion on the teacher's new conceptions of goals in project connects back to the discussion about teaching materials and the teacher's content knowledge. As the teacher and the students were not familiar with the topic of Electricity, the teacher and the students were seeking to arrive at the answers specified in the teaching materials. As a result, there was little room for flexibility in the process of arriving at the conclusions and in accepting different types of conclusions. Teaching materials have been seen to have the potential to influence teacher learning (Ball & Cohen, 1996). Therefore, it is worth considering that the teaching materials used and the teacher's unfamiliarity with the science concepts may have influenced the teacher's new conception of the science concepts and in turn of goals in PBSL.

- Nature of learning through project implementation

This section draws attention to the kind of knowledge the teacher developed as a result of practical experience of doing PBSL. In line with previous research on the implementation of PBSL (Krajcik et al, 1994; Ladewski et al., 1994; Marx et al, 1994), this study also shows that implementation of PBSL results in the teacher developing new conceptions of PBSL. As the teacher tried to implement PBSL according to her conceptions, she encountered many dilemmas that resulted in the development of new conceptions about the aspects of PBSL. The teacher developed new conceptions about the challenges associated with PBSL, teaching science content through projects, planning future projects and the use of teaching materials in PBSL. However, as one would notice, these new conceptions relate to the practical solutions for future implementations for PBSL. This is similar to the findings by Marx et al. (1994) which identified that teachers' learning through PBSL took the form of practical knowledge and not theoretical or propositional knowledge.

7.4 Limitations

Three limitations have been identified to have possibly hindered the quality of the research process. First, this research observed the implementation of two projects for a period of two months, the reader must be aware that these projects are not a representation of all projects implemented by the teacher. There is a chance that doing the same case study for a different project implemented by the same teacher may result in different findings. This study has been mindful of this fact throughout the process, and therefore, the WST and electricity projects are described in detail and the specific incidents from the projects that led to the findings are stated explicitly.

Second, data collection during observations primarily relied on taking notes. The obvious limitation of note-taking in real-time is the possibility of missing out on events that are relevant to the study. The use of abbreviations and short phrases helped in writing the notes fast and following the events of the class. Written notes were immediately transferred to a Word document, at this step the notes were elaborated and organized in a logical format as shown in FIGURE 9. Another limitation of writing observation notes is that the notes are to some extent the researcher's interpretation of reality (Gobo, 2011). To differentiate this interpretation from facts, the events that went on in class were organized sequentially as they happened. There was a special column in the notes that was meant for analytical reflections of the events that took place (See e.g. FIGURE 9). This way one could differentiate easily the exact event that happened and interpretations of it.

Finally, since I do not have a working proficiency in the Finnish language, I was unable to access texts that were relevant to the research but written in the Finnish language. Examples of some of those texts are science textbooks and the city's local curriculum. To overcome this limitation, I relied on research published about science teaching in Finland and clarified doubts related to the local curriculum with the teacher herself, my thesis supervisors, and peers from my MA thesis group.

7.5 Further research

Several directions for further research can be pointed at to better understand how to teach using PBSL, some of them are discussed here. This research identifies the need for further in-depth case studies to understand the implementation of teacher-initiated PBSL. More specifically, it would be beneficial if further case studies focus on specific aspects of PBSL such as, the process of scientific inquiry, the role of teaching materials, student discussions and the role of assessments in PBSL. Further research on teachers' learning in PBSL will inform how teachers can be supported and encouraged to do PBSL. This study recommends the use of online platforms as collaborative support structures for teachers, however, this is not a very well-researched subject. More research is required to understand the role of online platforms for teacher learning in PBSL. Research on how teaching materials can promote teachers' learning in the context of PBSL can be very beneficial as teaching materials can be a support structure in itself. Finally, longitudinal research on the development of students' scientific process skills from early childhood education or primary school is needed to understand how students develop these skills and how they can be better supported in the development.

7.6 Recommendations

The findings of a single case study cannot be generalized for a wider population. However, by comparing the findings of this case study to previous research on specific aspects of PBSL, this research is able to strengthen the recommendations made by previous research as well as provide some new recommendations. This study arrived at practical recommendations for three groups, namely, teachers, teacher educators, and policymakers. The teachers need to be aware that the implementation of PBSL is in itself a learning process. Teachers need to try to make the most of this learning process through continuous reflection. In their extensive research about teachers' learning through PBSL implementation, Krajcik and colleagues have identified that cycles of collaboration, enactment and reflection results in teachers' developing a new vision of PBS, rich conceptions of aspects of PBS and new strategies for enactment that are in line with theory (Krajcik et al., 1994; Ladewski et al., 1994; Marx et al., 1994). If there is a possibility, teachers should plan to collaborate, discuss, and learn with peers in the school or nearby schools. Another way to collaborate with other teachers and to learn is through online platforms that allow teachers to learn from each other's experiences. However, teachers need to be wary when using online platforms for PBL ideas, plans, and materials, especially platforms that are used as teachers' marketplaces. Teaching materials play an important role in the process of students' knowledge construction, therefore, teachers need to be critical about these materials and ensure that the materials borrowed are appropriate and of good quality.

This research shows that teachers require more support for implementing PBSL. It was seen that even the teachers with a high affinity towards PBL were not likely to implement it authentically without additional support (Marshall et al., 2010). Similarly, this case study also identifies the need for additional support for teachers to implement PBSL efficiently. In line with the suggestions by Aksela and Haatainen (2019), this research also suggests that providing training for pre-service and in-service elementary level class teachers to improve their content knowledge and PCK in science would ensure that teachers can better support students' science knowledge construction. More training and practice are needed for teachers to learn how to connect science concepts to students' real-life and develop driving questions that create a genuine need to investigate. As was seen in this study, teaching materials are not only tools for student learning but are also tools for teacher learning. Therefore, the provision of well-designed teaching materials for PBSL could potentially support teachers in developing their content knowledge and PCK during the implementation.

Support structures that can be utilized by teachers on an ongoing basis could benefit teachers. Already existing platforms to support teachers' project implementations (Ex. StarT program) should be strengthened and teachers should be made aware of the existence of such platforms. This research also identifies the need for policymakers and teacher educators to design the elementary class teacher education program in such a way that teachers are sufficiently trained to teach science through constructive approaches like PBL.

7.7 Final words

By studying one Finnish elementary class teacher's conceptions and implementation of PBSL, this case study has been able to discuss and draw attention to the various factors that played a role when the teacher tried to implement PBSL according to her conceptions. Through the experience of implementing PBSL, the teacher developed practical solutions for future PBSL implementation. In addition to identifying the need for further research to understand PBSL in the Finnish context, this case study also offers some practical recommendations which could possibly improve PBSL implementation in the elementary school context in Finland.

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