Challenges in phenomenon-based science education

Qualitative exploratory research on challenges and their opportunities of phenomenon-based science education in practice at two upper secondary schools in Norway

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Abstract

Phenomenon-based science education (PBSE) is an up and coming educational approach that originated from the philosophy 'phenomenology' and aims to reconnect science to students lives. Nowadays, the connection between scientific subjects and students' lives is in most cases lacking in secondary school science classes worldwide . This thesis aims to explore challenges for teachers when teaching PBSE and also to present possibilities to encounter these challenges, to help teachers who want to teach PBSE in their classrooms. Literature research was conducted to form a theoretical background for empirical explorative research. Case study research was conducted on two different Norwegian upper secondary schools with nine teachers in total to explore teachers' perceptions of the characteristics of PBSE, what competences teachers need when teaching PBSE and challenges that teachers encounter when teaching according to PBSE. Outcomes from the observations, one-on-one interviews and focus group interviews with the nine teachers from this thesis result in that they see the following characteristics of PBSE: lessons are introduced with a phenomenon connecting to the students experiences and world and students have to learn by themselves in their preferred way of learning. Furthermore, the teachers express that they need competences related to the process of implementing students' suggestions and ideas into the classroom and interdisciplinary teaching. Finally, the teachers point to time, timing and finding suitable phenomena as challenges when practicing PBSE in the classroom. The results from this thesis' can be used as background for further research on PBSE and to offer teachers possibilities to encounter these challenges and become (better) PBSE teachers.

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1 – Introduction

In 2015, the Dutch minister of education, culture and science, asked the Dutch Knowledge Coalition[1] to write a Dutch National Research Agenda (DNRA). The purpose of the DNRA was to "better equip Dutch researchers to find solutions to the challenges of our time" (Dutch Knowlegde Coalition, 2015, p. 5). Challenges of 'our time' are explained in the DNRA as complex issues that are defined by conflicting values, political pressure and economic interests. Many parties, approaches, new connections and partnerships are required to handle complex issues as air pollution or pesticides on crops. In the future, scientists will encounter more and more requests to solve complex issues (Dutch Knowlegde Coalition, 2015). To solve these complex issues, the development of interdisciplinary teamwork and critical thinking skills is important.

Many countries are coping with the problem of a decrease in the number of students that choose to pursue a study in science (Barmby et al., 2008). Sjøberg & Schreiner (2010) studied student' attitudes towards science and found that students are interested in science (for example, citizen science), however, not in school-based science. Figure 1 shows a graph presented by Sjøberg & Schreiner (ibid.) illustrating that students in most western countries show little interest in becoming a scientist.

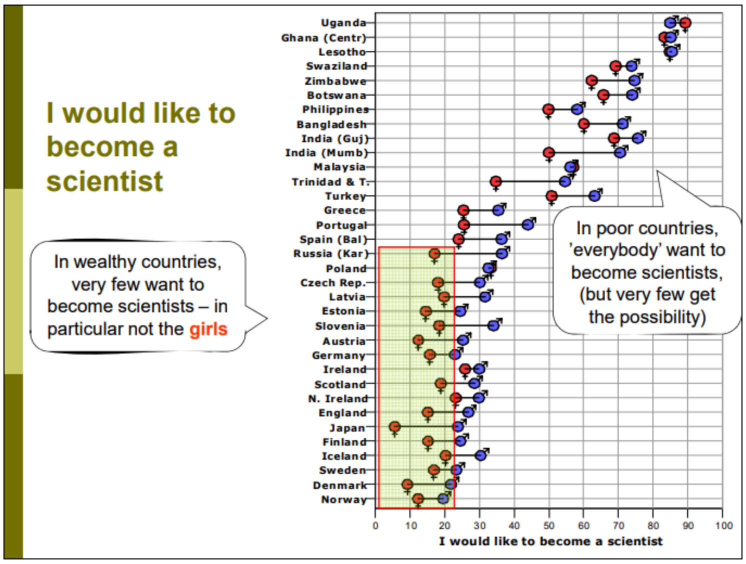

Figure 1 Results 'I would like to become a scientist' (Sjøberg & Schreiner, 2010, p. 27)

[1] Consisting of: Dutch universities, universities of applied sciences, employers (VNO-NCW and MKB Netherlands), university medical centers, the Dutch organization of scientific research, and the Royal Netherlands Academy of Arts and Science.

Østergaard (2017) refers to research showing that students are becoming more and more disconnected from science. One reason for this disconnection could be related to an existing gap between scientific subjects or phenomena presented in the science classroom and students' lifeworld experiences (Dahlin, 2001). Dahlin (2001) further elaborates on the necessity of bringing aesthetic perception back to the student to recreate the connection between students and science ('aesthetics' = how people characterize beauty, 'perception' = the ability to see, hear, or become aware of something through the senses; 'aesthetic perception' = the ability to see, hear or become aware of the beauty of things through the senses (Datta et al., 2006; Oxford dictionairy). To bring the aesthetic perception back into the science classrooms, the philosophy of phenomenology can be used. Phenomenological activities as thinking, feeling, perception and imagining in the classroom could lead to familiarity of students to science and bridge the gap between students' experiences and scientific concepts (Dahlin, 2001).

The educational approach phenomenon-based science education (PBSE) can be seen as the application of phenomenology in science education. PBSE is an educational strategy based on "the notion of phenomenology as an attempt to understand phenomena from within" (Dahlin & Østergaard, 2009, p. 2) and aims to develop a new generation of students capable of dealing with complex issues and to bridge the gap between the students and science. Therefore, to bring PBSE into the modern classrooms might help solving the two abovementioned problems of present science education (lack of skills to handle complex issues and the disconnection from science and the lifeworld).

Since 1999 the Norwegian University of Life Sciences (NMBU) is developing PBSE as an educational course in their science teacher education program. This master's thesis is based on empirical research performed during my stay at the NMBU.

Overall, there is little research available that focusses on PBSE in the classroom or on the challenges that students and teachers encounter when applying phenomenology in science teaching. This master's thesis therefore aims to fill the knowledge gap in the practice and application of PBSE in the classroom. This thesis will provide a list of challenges for (future) teachers who (want to) use PBSE, to help them in their journey of becoming (better) PBSE teachers. Additionally, examples of how teachers encounter the challenges will be provided.

This master's thesis answers the following research question: What are the main challenges for applying phenomenon-based education in the secondary school science classroom? To provide a background for answering the research question, sub-questions were formulated:

1. What are the characteristics of phenomenon-based teaching in practice?

2. What competences do teachers need to successfully implement phenomenon-based science education?
3. What are the differences and similarities in implementing and applying phenomenon-based science education in different disciplines in science education?

In order to answer the abovementioned questions, literature study was first conducted to explore what the state of the art is regarding research on PBSE. Furthermore, empirical research was conducted on schools that are working with PBSE. In the classrooms on these schools, case study research was conducted to see how PBSE was practiced. The case study research consisted of observations of the classrooms, one-on-one interviews and focus group interviews with nine teachers on two different schools. Data from the case study research was analyzed based on the research and sub-questions, providing insight into different challenges and possible ways to encounter the challenges related to PBSE. This master's thesis is concluded by a discussion on how the case study research was conducted and implications for further research on the thesis' topic.

2 - Theoretical framework

2.1 - Phenomenology

“Historically, phenomenology as a concept or a research practice has existed for about two centuries. Hegel’s *Phänomenologie des Geistes*, which appeared 1807, is perhaps the first well-known use of the term, even though Edmund Husserl is generally considered to be the inaugurator of phenomenology as a modern philosophy and research methodology” (Østergaard et al., 2008, p. 94).

According to Husserl (1970, p. 23), phenomenology has the goal to follow Husserl’s dictum “to go back to the ‘things themselves’”. The author also says that ‘going back to the things themselves’ allows people to use a way of thinking that aims to be free of assumptions and prejudices (ibid., p. 130). Furthermore, Husserl found that the use of phenomenology can provide a basis for the connection to the ‘things themselves’ by letting the students’ open-mindedly explore phenomena present in the world and to become aware of their relationships with the phenomena (Husserl, 1970; Østergaard et al., 2008). In science education, ‘things’ represent scientific issues or phenomena subjected in science classes (e.g. forces, atoms, light, soil). Husserl’s statement “to return to the things themselves” (Husserl, 1970, p. 23) can be interpreted as that phenomenology should be practiced through activities or experiences the students must encounter for themselves.

Literature shows that there are many different definitions of phenomenology and defining ‘phenomenology’ is not an easy thing to do. For example, Østergaard et al. (2008) stated that phenomenology is a philosophy dealing with the basic questions of epistemology (philosophy of knowledge) and ontology (philosophy of being). Phenomenology can be applied in many different ways in complex fields like anthropology, research methodology and science education. Van der Mescht (2004) writes that phenomenology's most distinguishing feature is the fact that it focuses on the meaning human beings give to their experience. A few years later Dahlin & Østergaard (2009) wrote that phenomenology never neglects sense experience, however, uses the sense experience as a starting point for understanding, systematic investigation and reflection.

In an article, that criticizes the theoretical bases of science education, Dahlin (2001) mentions that the main objective of phenomenology in science education is “to elucidate and clarify our experience of knowledge and learning about nature – through thinking, feeling, perception, imagination, or whatever. Such inquiry takes us back to our immediate lifeworld, the ultimate ground out of which all genuine, human learning must grow" (ibid., p. 470).

Characteristics of the application of phenomenology in education (PBSE) can be derived from the literature mentioned above: in PBSE the students have the opportunity to experience the provided phenomena themselves and a link should exist between the students' experienced world and the phenomenon. PBSE can be practiced through activities as thinking, feeling, perception and imagining to learn about nature and the students role in nature and senses play an important role in PBSE in practice.

2.2 – PBSE – a definition and characteristics

Similar to phenomenology, clear definitions of PBSE are not easy to find. The first use of the term 'phenomenon-based science education' was in 2009 used as an educational approach (Dahlin & Østergaard, 2009). Knowledge gathered from literature and conversations and interviews with teachers working with PBSE and experts on PBSE, concluded in the creation and elaboration of a definition for PBSE:

PBSE is an educational approach that always has a phenomenon as starting point in the lessons. The students have to be able to relate and connect to the phenomenon through their sense experiences and life. When the phenomenon is brought into the science lessons or the lessons to the phenomenon, the phenomenon triggers the students' interest and motivation and engages them to observe it. Through a learning process that involves observations, questions and suggestions, the students will gain knowledge about the phenomenon and the scientific theory behind the phenomenon. The role of the teacher in PBSE is to be a facilitator of the learning process of the students. Therefore, the teacher tries to motivate the students to find their own preferred way of learning and working and creates space to facilitate the students' preferred ways of learning and working.

As the definition above states, phenomena are at the center of PBSE. In addition, the senses play an important role in PBSE. A phenomenon can be a physical object, for example, an apple, however, it can also be an experience of something the students or the teacher encountered, for example, the popping of your ears when you are flying in an airplane or driving through the mountains (Dahlin et al., 2009; Penuel et al., 2018). As mentioned in Chapter 2.1 PBSE has to connect the students to science. Phenomena can be used to create this connection, however, only when the students are engaged for learning with the phenomenon, therefore, it is important to find suitable phenomena in which the students are interested and to which they can connect to foreknowledge or previous experiences.

2.3 – Comparing PBSE to other educational approaches

The definition of PBSE gives some guidance to what PBSE means, however, the definition and literature on PBSE do not elaborate on how PBSE should be practiced. Educational approaches similar to PBSE can help to find characteristics for working with PBSE. Inquiry-based science education (IBSE), problem-based learning (PBL) and experiential learning (EL) are examples of educational approaches similar to PBSE. Table 1 provides a literature-based overview of similarities and differences between respectively IBSE, PBL and EL of and challenges of IBSE, PBL and EL.

Table 1 Similarities, differences and challenges of IBSE, PBL and EL

	IBSE	**PBL**	**EL**
Similarities with PBSE	- Developing conceptual understanding of scientific phenomena. - Use phenomenon to engage and motivate students for learning. - Teaching in an authentic context (Dahlin & Østergaard, 2009; Uum et al., 2016).	- Reflection and co-operation are important in learning. - Focus on learning skills instead of gathering knowledge. - Teaching in an authentic context (Delva et al., 2000).	- Experience of the student is the focus. - Using the students' life and learning experiences to engage the students for learning. - Involve students in something that is personally significant or meaningful for them. - Teaching in an authentic context (Andresen et al., 2000; Dahlin & Østergaard, 2009).
Differences with PBSE	- Aim of the introduction phase IBSE: to confront the students with a problem or phenomenon connected to an authentic research practice to excite students. PBSE: the students should experience the	- PBL focusses on problems and how to solve them. PBSE does not focus on problems and their solutions but on experiencing (Delva et al., 2000).	- EL focusses on experience to structure the students' learning processes. PBSE focusses on phenomena to structure the students' learning processes (Andresen et al., 2000; Dahlin & Østergaard, 2009).

	phenomenon with all their senses (Dahlin & Østergaard, 2009; Uum et al., 2016).		
Challenges	- To find and design inquiries that include all concepts and increase the students curiosity and motivation for learning. - To develop assignments with the right amount of guidance for the students (Barron & Darling-Hammond, 2010).	- To find time for preparation and lessons. - To find suitable problems (White, 2001).	- To facilitate the connection between science and the students personal experiences. - To find time for preparation and experiencing in the lessons. - To find an authentic environment (Hedin, 2010).

Table 1 shows that there are a lot of similarities between PBSE and respectively IBSE, PBL and EL. IBSE, PBL and EL all have only one difference with PBS,. The challenges mentioned in Table 1 might be applicable on PBSE, data collected by this thesis will provide knowledge on similarities in challenges between the different educational approaches. The challenges provided in Table 1 will be discussed further and compared in relation to the findings of this thesis in Chapter 4.

2.4 – Motivation

The phenomena should make a connection to the students' life world and has to be meaningful for them. Ryan and Deci (2000) conducted literature study on motivation and learning. They mention that students have different forms of motivation, see Figure 2. Motivation created by PBSE is focused on the identification and integration styles of motivation with as goal to eventually proceed to intrinsic motivation. In the identification style, the student has identified the personal importance of the phenomenon. Ryan and Deci mentioned an illustrating example for the identification style: "A boy who memorizes spelling lists because he sees it as relevant writing, which he values as a life goal, had identified with the value of this learning activity". However, PBSE focusses on more than only identifying with the phenomenon, the students also have to experience and work with the phenomenon themselves. Therefore, is integration one of the focus styles regarding motivation in PBSE. To integrate a phenomenon in learning, the student has to become autonomous to it and must understand its meaning and meaningfulness in the students' life.

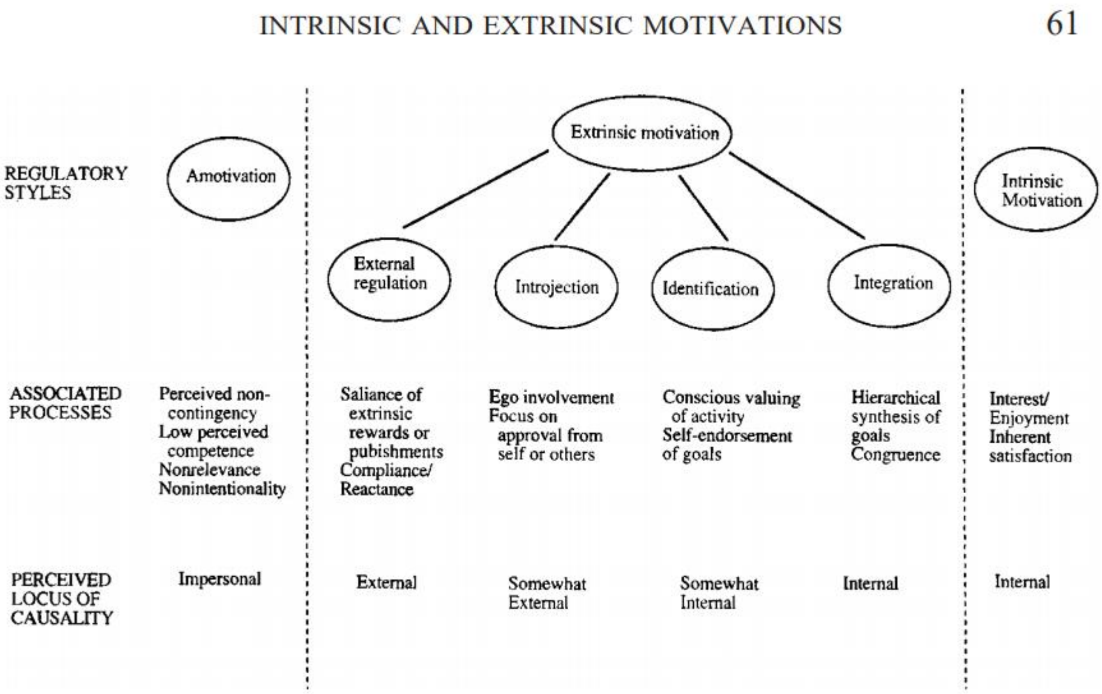

Figure 2 Motivational styles (Ryan & Deci, 2000)

The step from integrated and identified motivation to intrinsic motivation is very small. Both identified and intrinsic motivation are associated by Ryan and Deci (2000) with enjoyment of school, interest and positive coping. Integration and intrinsic motivation share qualities as being autonomous and self-determined. To achieve intrinsic motivation, self-determined learning has to be provided in the classroom. Relatedness, autonomy and social contextual conditions that support the students' feelings of competence are necessary for students to become more self-determined in learning. PBSE has the goal to facilitate these three conditions for learning and, therefore, to facilitate intrinsic motivation for learning. Chapter 5 will show if these three conditions are present in the practice of PBSE within the range of this thesis.

3 - Methods

What are the main challenges for applying phenomenon-based education in the secondary school science classroom? In order to find answers on the research question and the sub questions multiple case study research was conducted (an overview of the research design is presented in Figure 3). Case study observations, one-on-one interviews and focus group interviews were used as methods of data collection. The multiple case study contained two different sites (schools) with all together nine cases (teachers). The first site was an upper secondary Waldorf school in Oslo and the second site was an ecological agricultural upper secondary school in Aurland. Both sites are located in Norway and include classes in different science related subjects. This chapter elaborates on the characteristics of the sites and cases.

The teachers at both sites were typical cases of working with PBSE, this means that they are among the few teachers who teach PBSE. Two different schools were included to increase the reliability in this study because every school has their own rules and regulations and their own ways of teaching (Denscombe, 2007; Drost, 2011). Multiple teachers were included in each school to increase the reliability because every teacher teaches in his or her own way and have different backgrounds and interests.

3.1 - Site 1 - Oslo By Steiner Skole

The first site was the Oslo By Steinerskole (OBS). This is a Waldorf upper secondary school (*videregåene skol*e) in the center of Oslo. Upper secondary schools in Norway normally have students from the age of 16 to 19 divided in three years (VG1, VG2 and VG3). The students come from different lower secondary schools. At Norwegian upper secondary schools students are being prepared for studying at a university.

The first teacher has three classes of chemistry lessons in VG1, VG2 and VG3. VG1 consists of 32 students and followed chemistry as part of *naturfag* (an introductory course for chemistry, physics and biology). The VG1-students followed two weeks of education in chemistry, followed by two weeks of physics and two weeks of biology. VG2 (34 students) and VG3 (13 students) had lessons in regular chemistry where they followed chemistry lessons the whole year (not only for two weeks as in *naturfag*). VG1, VG2 and VG3 had the same chemistry teacher and the lessons were all in the same classroom (appendix I). The teacher of the chemistry classes at OBS are be addressed in this thesis as O1 (OBS, teacher 1). Observations was be conducted in all three classes of O1. O1 attended a one-on-one interview and the OBS focus group interview.

The two other classes at OBS were *hovedfag* physics (VG1) and general physics (VG3). The setup was the same as in chemistry. Just as in chemistry, the 32 VG1 students had two weeks of *naturfag* physics and VG3 (12 students) had physics year-round. Observations were conducted for 1 week (see research design, Figure 3). Both physics classes were taught by O2, and in the same classroom as the chemistry lessons (Appendix I). Both the VG1 and VG3 physics classes were be observed. O2 attended a one-on-one interview and the OBS focus group interview.

In addition to the interviews with O1 and O2, a retired physics, math, history and social sciences teacher (O3) also attended the OBS focus group interview and participated in a one-on-one interview. O3 was invited to participate in the research based in advise from O2 and Edvin Østergaard (supervisor).

3.2 - Site 2 – Sogn Jord- og Hagebrukskole

The second site was the Sogn Jord- og Hagebrukskole (SJH), an ecological agricultural upper secondary school at the west coast of Norway. At SJH they have two classes: VG2 (20 students) and VG3 (13 students). At SJH all students follow the same education, expect, at some moments in the year where they could choose a course that matches their interest. Observations were conducted for two weeks in soil management for VG2 (teacher S2), animal husbandry for VG2 (teacher S3), beekeeping for VG3 (teacher S4), landscape management for VG3 (teacher S5) and horticulture for VG2 (teacher S6) an overview of the observations was illustrated in Figure 3. Only 13 VG2 students follow the horticulture course as horticulture was a course that they could choose. 13 of the students chose horticulture, the other students chose other courses, which were not part of this multiple case study. The VG2 and VG3 classrooms were organized similar and presented in appendix I, the horticulture classroom was in the greenhouse and a map of this classroom is also presented in appendix I. Teacher S1 is the head of SJH and has worked as a teacher educator and researcher together with one of the supervisors of this thesis, Edvin Østergaard, on PBSE (e.g. Dahlin et al. (2012); Østergaard et al. (2008); Østergaard et al. (2017); Østergaard et al. (2007)). S1 is an expert on PBSE, nonetheless S1's classes were not observed for this thesis due to S1 not having any classes during the two weeks visit at SJH

SJH is a unique school in Norway. Normally, students going to upper secondary education are in the age between 16 and 19, coming straight from a lower secondary school. At

SJH there is no boundary on age. The average age of VG2 this year was around 26 years and from VG3 around 23 years. Besides the age difference, there was a big range of different backgrounds between the students of both classes. Some students at SJH came from a lower secondary school at the age of 16, others had already finished a bachelor and/or master at a university. Some others have been working in their field of expertise and wanted to learn more about ecological agriculture due to a career switch or, for example, planning to take over the family farm. After SJH the students are educated to work on an ecological farm, not to go to a university as other upper secondary schools in Norway (like OBS). SJH does not represent other Norwegian upper secondary Norwegian schools. The reason SJH was chosen for this study was that this thesis is an explorative study and, therefore, seeks for a broad view on PBSE and its challenges in practice.

3.3 - Methods of data collection

This chapter elaborates on the different data collection methods used during this case study research. Figure 3 illustrates the timeline of the data collection methods from this master's thesis multiple case study.

Figure 3 Research design, empirical conducted from week 1 to week 6.2018

The research design and timeline of the data collection methods is presented in Figure 3 (for example: observations in the VG1 class with O1 at OBS was conducted nine times during week 1 and 2).

The main part of the data collection consists of data from observations. To provide insight into the practice of PBSE in the classrooms, 35 lessons from 7 different teachers (no observations were conducted with O3 and S1 due to them not teaching at the time of the observations) were observed. During the observations the focus was on different focus points (see Appendix II), for example: How does the teacher introduce the phenomenon and what is the phenomenon? What motivates the students to do the exercises? In what way do the students work with the phenomenon? A booklet was used to write down focus points during the observations. The focus points were based on the guidelines for the application of PBSE from literature presented in Chapter 2.1, the challenges from other educational approaches (Chapter 2.3) and outcomes from personal conversations with Edvin Østergaard. The observed lessons were not recorded (audio or video). The observations provided knowledge on characteristics of PBSE in practice (sub-question 1), competences that teachers need to implement and use PBSE in the classroom (sub-question 2) and challenges that teachers have when they use PBSE (research question).

The notes on the focus points from the observations were coded: first the notes were digitalized and categorized by what sub/research question the note was an answer on. The coding process was carried out by using color coding in Microsoft Word. After the first categorization, each sub/research question (after categorizing) contained multiple subject, for example, sub-question 1 contained 13 different characteristics noticed in the observations, (e.g. evaluation of the learning process, interdisciplinary work, asking questions to engage and motivate students for learning). Coding continued by checking the notes from every lesson on the presence or absence of the 13 different characteristics, 8 different competences (sub-question 2) and 11 main challenges (research question). From the identified characteristics, competences and challenges, some elements stood out as frequently observed and by identifying interesting connections between the different methods of data collection. For example, eight out of nine teachers said in the one-on-one interviews that phenomena are important in PBSE, however, only 24 of the observed lessons showed phenomena in the lessons. Notes categorized for sub-question 3 contained little agreement of differences and similarities in challenges in different disciplines, so these findings were summarized and presented in Chapter 4.3.

Besides collecting data from observations, data from nine one-on-one interviews was collected. The interviews were conducted one-on-one (one interviewer and one interviewee), therefore the interviewee could speak freely without the notion of other participants judging his or her thoughts. The one-on-one interviews were focused on topics (see Appendix III for interview questions) and, therefore, could dive into the experiences and thoughts of the interviewees, in this way, in-depth data was collected from interviews. Data collected in the one-on-one interviews provided knowledge about characteristics of PBSE in practice (sub-question 1), competences that teachers need to implement and use PBSE in the classroom (sub-question 2), differences in implementing PBSE in different disciplines (sub-question 3) and challenges that teachers have when they use PBSE (research question). The one-on-one interviews were conducted once per teacher (see Figure 3) and audio was recorded.

The audio recordings from the one-on-one interviews were transcribed and categorized as in the observation notes (color coded per sub/research question). Transcribed categories were divided between the different characteristics, competences and main challenges found while coding the observations and more characteristics, competences or main challenges were added when necessary. Similar to the observations, the most important characteristics, competences and main challenges are discussed in Chapter 4. The transcripts categorized in sub-question 3 were coded in the same way as the observations, this category is summarized and presented in Chapter 4.3.

The data collected from observations and one-on-one interviews was not enough to fully answers the research question(s). The two sites of this master's thesis research were schools where multiple teachers participated in the research project, making it possible to conduct focus group interviews with multiple teaches. In the two focus group interviews the participants (3 (OBS) and 2 (SJH)) discussed the challenges and possibilities of PBSE in education in general and in the light of their own field of science (Denscombe, 2007; Kvale & Brinkmann, 2009). The focus group interviews were conducted with the participants (teachers) of one site (SJH or OBS) and provided knowledge on differences in implementing PBSE in different disciplines (sub-question 3) and challenges that teachers have when they use PBSE (research question). The focus group interviews were audio recorded. Data analysis on the focus group interviews was conducted as in the one-on-one interviews.

All three data collection methods on a single site were practiced in the same time frame (see Figure 3). However, due to logistic problems, some one-on-one interviews and the focus group interview at OBS had to be conducted after the stay at SJH. Data triangulation occurred as the data from observations and/or one-on-one interviews shed new light on the discussion during the focus group interview (which were conducted after the observations and the one-on-one interviews). The data collected from the observations were analyzed before conducting the one-on-one interviews and examples from the observations were used in the one-on-one interviews to ask the teachers, for example, about their behavior in the lessons and their thoughts on what happened during the observations. In addition, the data from observations and one-on-one interviews were combined and used as a background for the subjects which were discussed in the focus group interviews. Challenges of working with PBSE that presented itself during the observations, were mentioned and discussed by teachers in the one-on-one and focus group interviews. The data collected from the one-on-one interviews, observations and the focus group interviews were combined to answer the research question.

4 – Results

In Chapter 2.2 the definitions of a phenomenon and PBSE were formed according to literature. In the one-on-one interviews during this research, one of the questions was to define PBSE. 4 out of 9 teachers also defined a suitable phenomenon for PBSE. All 4 teachers who defined a suitable phenomenon for PBSE said that a phenomenon needs to connect or relate to the students life. The phenomenon has to be meaningful for the students and engage them in learning. This definition combined with the definition from the literature in Chapter 2.2 makes the following definition of a phenomenon: a physical object or experience connecting the students' life with the scientific subjects to be taught and engages and motivates the students for learning.

This chapter presents the results of the analysis of the data collection in this masters' thesis. Chapter 5 will elaborate on the results and link them to the literature from chapter 2, conclude and discuss this thesis.

4.1 – Characteristics of PBSE in practice (sub-question 1)

Data collected from the case study observations and one-on-one interviews provide answers on sub-question 1 (characteristics of PBSE in practice). During the one-on-one interviews, the teachers were asked the question: What is your definition of PBSE in science education? (for the complete interview guide, see Appendix III). Answers on this question were combined and are discussed in this chapter. The focus points used during the case study observations that provided characteristics of PBSE in practice: What characteristics of PBSE is the teacher using? In what way? And how is the schedule of the lesson? (for all the observation focus points, see Appendix II).

The focus group interviews focused on the challenges of PBSE, not on the characteristics of PBSE in practice, therefore, data collected from the focus group interviews was not used to answer sub-question 1.

4.1.1 - Introduction of the subject with a phenomenon

Observations showed that in 24 out of the 35 lessons the scientific content was introduced with a phenomenon. On the contrary, interesting is that in 11 of the 35 lessons the scientific content was not introduced with a phenomenon. Reasons for not using a phenomenon to introduce the scientific content were tests, pre-test and working sessions. An example of an introduction with a phenomenon comes from one of O2's lessons about force distribution and bridges. O2 brought boxes with wooden bridge parts. The students instructed O2 to build the bridge, O2 only acted on the students' instructions. The first two bridges collapsed and when a bridge collapse. This led to the students discussing more loudly how to build a better bridge the next time and instructed O2 on how to build a new bridge. The students seemed engaged with building bridges and finding ways for the bridge to not collapse as the students asked a lot of questions and posed more alternatives for bridges every time a bridge collapsed. When the bridge collapsed or did not collapse, O2 explained how the forces were distributed in the bridge and why the bridge collapsed or not. In this example O2 used bridges as phenomena to explain the subject force distribution.

Furthermore, the observations showed that in 8 out of the 24 lessons where subject was introduced with a phenomenon, the teachers mentioned that the subject was a theoretical one. This observation could be related to the teachers mentioning that they found it challenging to find phenomena for theoretical subjects, however, they found a solution and used historical phenomena to explain the subject. For example, O2 explained to the students how experiments on the relativity theory were done in the past as was not possible to do experiments on the relativity theory in the classroom. Therefore, O2 explained how the experiments should have been done when it was possible to do the experiments in the classroom. The students seemed engaged for learning about how the researchers in the past did experiments and to find out how the relativity theory works by asking a lot of questions and answering all O2's questions. In this example, O2 used historical researchers and their experiments as phenomena to explain the relativity theory.

Data collected from the one-on-one interviews showed that not all teachers thought starting with a phenomenon to introduce a subject is an important characteristic for PBSE.

However, six of the nine teachers thought introducing the subject with a phenomenon is an important characteristic of PBSE in practice. The most important reason teachers provided for introducing the subject with a phenomenon is that the phenomenon engages and motivates the students for learning. The 3 other teachers did not mention introducing the subject with a phenomenon as an important characteristic of PBSE. Interesting is that the 3 teachers who did not specifically mention using phenomena to introduce the subject in their lessons were also the 3 teachers who did not use phenomena to introduce the subject in their lessons. During the one-on-one interviews, it was not specifically asked if the teachers thought introducing the subject with a phenomenon is an important characteristic of PBSE, however, they were asked to write down a list of characteristics of PBSE.

4.1.2 - The phenomenon has to connect to the students' life world

One of the questions during the one-on-one interviews was: "what are characteristics of a suitable phenomenon in PBSE?" On this question, six out of nine teachers answered that the phenomenon has to connect to the students' life world and that the phenomenon has to be meaningful for the students, as in these examples from teachers: "The way to learn best is to have a connection to the subject. You have to find an authentic situation, make a case that students can relate to" (S2). "The phenomena should be able to find a place in their minds, like a coat hanger, that makes them motivated and interested" (O2). The other 3 teachers did not mention that to connect the phenomenon with the students' and their lifeworld was an important characteristic for PBSE.

27 of the 35 observations showed that teachers connected the phenomenon to the students' lifeworld. 7 of the observed lessons did not use a phenomenon and, therefore, no connection between the phenomena and the students' life world was observed. Reasons for not using a phenomenon were tests and a working session. In 1 observation, S2 connected the phenomenon to the students' life world by giving the students a piece of soil from the greenhouse they were going to work in later that year. S2 told the students that this was the soil they were going to work with in the horticulture lessons. The students had been working with this soil earlier in the year and, therefore, S2 referred to the lessons in which they had used the soil. S2 connected the soil to the students life's through referring back to experiences they had and going to have with the soil.

Interestingly, in the focus group interviews the characteristic 'phenomena should connect to the students' life world' was only mentioned by S6 and S1: "One of the most important features of PBSE is that education should have a close connection to real life and this can be arranged with phenomena which have a connection to the students' real life" (S1). In the OBS focus group interview, this characteristic of PBSE was not discussed.

4.1.3 – Students should learn by themselves in their preferred way of learning

30 out of the 35 observations showed that teachers let the students learn by themselves and helped the students by facilitating their needs. In the 5 lessons that did not include this characteristic, the teachers instructed the students from the start to the end of the lesson, they used the blackboard and PowerPoint to illustrate their instruction. In these 5 lessons, the teachers asked few questions during the instruction, and the students also asked fewer questions then in the lesson that were characterized as 'students learning by themselves'. An example of letting students learn by themselves is from one of S3's working lessons: the students had to choose one of the subjects they already encountered in the lessons before or were going to encounter in the upcoming lessons. If they did not want to use one of the subjects S3 presented, the students could come to S3 and argue why they could use the subject they chose. S3 motivated the students to think about their subject. When the subject was approved by S3, the students started working on the assignment. When students wanted to know something or had questions they could ask S3 and S3 would come and help. It was clear that the students were motivated, because, they were working hard and in silence. S2 says in the one-on-one interviews that the students are motivated for working when they choose their own subject: "The students are way more interested when they chose a part of the subject they want to work with. They have their own motivation then".

In 7 out of 9 one-on-one interviews teachers mention the importance of being a facilitator of learning for the students and the students have to learn by themselves and work in the way they prefer. In Chapter 2 it is mentioned that PBSE should be practiced through experiences the students must encounter themselves. When using the characteristic 'let students learn by themselves in their own preferred way' in PBSE it is possible for the students to experience the science themselves and encounter the subjects in their preferred way, however, when they need "handholds" you have to be there for the students to help them: "When you let the students find their own way of working, they will all find their challenges in learning, their own challenges. You have to be able to give handholds and provide help when the students need that" (S3). 2 other teachers did not mention they let de students work in their preferred way and. There was not explicitly asked for this characteristic of PBSE in the one-on-one interviews, the teachers were free to name the characteristics they thought were important for PBSE.

Summarized, the most important characteristics for PBSE in practice resulted from the data collection are: PBSE starts with a phenomenon that is meaningful for the students and connects to the students' life world and the student have to learn by themselves in their own preferred way of learning. This paragraph showed that not all lessons included phenomena for introducing the subject. Reasons for not using phenomena were, for example, tests and working sessions and the teachers who designed the tests said in the one-on-one interviews that they refer back to the phenomena presented in de previous lessons, however, that was not visible in the tests. Therefore, the teachers try to implement phenomena in tests, however, no phenomena were found in the tests, this might be because the teachers find it a challenge to include phenomena into tests.

Finding a phenomenon that is meaningful for the students and connects to their lives is important, however, it is also a challenge. Chapter 4.4 discusses the challenges of teaching PBSE found in this research and Chapter 5 provides possibilities to encounter the challenges.

4.2 – Teacher competences for PBSE (sub-question 2)

Data collected from the observations and one-on-one interviews provided answers on sub-question 2 (teacher competences for PBSE). During the one-on-one interviews, the teachers were asked to elaborate on competences they find important when teaching PBSE and when the teachers had experience in teaching with other educational approaches if the competences were specifically for teaching PBSE or for teaching in general. Answers on these questions were combined and discussed in this chapter.

Competences for teachers when teaching PBSE was not discussed specifically in the focus group interviews, however, some teachers still mentioned important competences when they discussed the challenges of PBSE. The analyzed data which is useful for answering the 2nd sub-question is provided in this chapter.

4.2.1 – Implementing student ideas in the classroom

24 out of 35 of the observations showed that teachers used and implemented students ideas in the classroom. Striking is that the 11 lessons where the students' ideas were not implemented all were lessons from O1. A possible reason for not implementing the students ideas in the lessons was that O1 did not mention implementing students ideas in the lesson as an important competence for teaching PBSE in the one-on-one interview. The observed lessons were in the middle of the year so the students might have gotten used to O1's ways of teaching. An example of implementing students ideas in the lesson was from O2's lesson on experiments and formulas about forces. Students asked during the previous lesson if O2 could arrange a lesson in which the students could use the formulas they learned during the lesson in practice. O2 designed an experiment in which the students could connect the formulas and theory to the practice of physics. Furthermore, the students had to connect the formulas to force distribution in practice on a force board (Figure 4). The students had to find the right angle for balancing the weights and had to use the formula they had discussed the previous lesson. At the end of the lesson O2 asked the students if they understood the connection between the formulas and the practice of physics better after this experiment, the students answered yes.

Figure 4 Experiment with forceboard O2

In 7 of the 9 one-on-one interviews the teachers mentioned that implementing students' ideas and suggestions in the lesson was a competence for teaching PBSE: "You [the teacher] should be open for the ways students want to learn and for suggestions from the students" (S3).

The other 2 teachers (S6 and O1) did not mention the competence specifically, however, they also did not say that the competence is not important for teaching PBSE. However, in the lessons of S6 the characteristic 'implementing students' ideas' was observed even though S6 did not mention 'implementing students' ideas' as important competence.

4.2.2 – Interdisciplinary teaching

The one-on-one interviews showed that 7 out of 9 teachers thought interdisciplinary teaching was an important teacher competence when teaching PBSE because: "Then [when using interdisciplinary teaching] the students see that different disciplines have things to do with each other and are connected" (O2). The other 2 teachers did not mention interdisciplinary teaching as a competence for teaching PBSE. However, O2 also discussed a negative side of interdisciplinary teaching: "It is tempting to work interdisciplinary. However, I don't want history to become mathematics because then the students who are not good in math, are maybe getting behind in history because I use a lot of math in history, so I try to not do that that all the time."

Half of the observed lessons did not include interdisciplinary teaching (17/35). O2's skepticism towards interdisciplinary teaching was visible in the observations as 6 out of the lessons that did not include interdisciplinary teaching were lessons from O2. Striking is that the other lessons, that did not include interdisciplinary teaching, were from the 2 teachers who did not mention interdisciplinary teaching as an important competence for teaching PBSE. Contrary, half of the observed lessons did include interdisciplinary teaching. For example, in one of O1's lessons. O1 connected the molecule bonds to cells in living organism and explained that the students had already discussed cells in biology lessons and asked them what they could recall from the biology lessons, O1 used the answers on these questions to further explain molecule bonds.

Interdisciplinary teaching was discussed in the focus group interview at SJH and both teachers mentioned that interdisciplinary work was crucial for teaching PBSE and that teachers should have the competence to work interdisciplinary. Interdisciplinary teaching was not mentioned during the focus group at OBS.

In conclusion, using and implementing students' ideas in the classroom and interdisciplinary teaching are 2 of the most important competences teachers need when teaching PBSE. The competence of implementing students' ideas in the classroom was not mentioned by 2 of the teachers. However, through observations it became clear that one of those teacher actually included implementing students' ideas. Contrary, almost all of the lessons of the other teachers did not include implementing students' ideas. One reason for S6 not mention the implementation of students' ideas in the classroom could be that S6 thought this competence was not specifically for PBSE, however, for education in general. Interdisciplinary teaching was only observed in half of the lessons. However, 7 of the 9 teachers mentioned this as an important competence for teaching PBSE. The reason for not using interdisciplinary teaching in all the lessons could be that teachers thought interdisciplinary teaching was a challenge.

4.3 – Differences and similarities between disciplines (sub-question 3)

Data collected from the one-on-one interviews and focus group interviews provided answers on sub-question 3 (differences and similarities between disciplines). During the one-on-one interviews, the teachers were asked to elaborate on differences and similarities between different disciplines and on specific challenges for their discipline. Answers on these questions were combined and discussed in this chapter.

During the focus group interviews the teachers were asked to write down challenges specific for their discipline and to make a list of disciplines and order them on how easy or difficult it was to teach the disciplines in the light of PBSE. The analyzed data that is useful for answering the 3th sub-question is provided in this chapter.

In the OBSE focus group interview, O1 mentioned that: "Mathematics is the most difficult discipline for teaching PBSE and for finding suitable phenomena (…) it is easier to relate to subjects from biology and chemistry and the students can use, for example, their own body." This quote shows that O1 thought it was more difficult to choose suitable phenomena which connected to the students' everyday life within mathematics than for the other science disciplines.

In addition, one-on-one interviews show that science disciplines including living organisms (biology, animal husbandry, beekeeping, horticulture) have difficulties in finding or going to a phenomenon that explains a complex subject as ecology or life cycles: "It is a challenge to go to the animals or bring them [the animals] in the classroom (S3)."

The OBS focus group discussed the similarity of teaching about models and converting formulas and models to interesting real-life examples in all science disciplines: "Another problem in physics and in all sciences I think is that you have to learn them [the students] something about models too. Since, that is part of the curriculum and a big part of physics. I want the students to understand what is a model and what is the difference between a model and reality. It is an important challenge for all sciences to connect the models to real life."

Summarized, there are similarities between disciplines when working with PBSE, for example, working with models and complex concepts and living organisms. Some disciplines do not have these similarities, for example, mathematics does not necessarily work with living organisms. Another similarity was that in all disciplines it was a challenge to use a phenomenon when this phenomenon was not easily taken into the classroom, for example, livestock. The last important similarity was that subjects that include a lot of theory were challenging to find suitable phenomena for. A difference between different disciples was that for disciplines as biology and chemistry it was easier to find phenomena than for more theoretical disciplines.

4.4 – Challenges in PBSE (research question)

Data collected from the case study observations, one-on-one interviews and focus group interviews provided answers on the research question (What are the main challenges for applying phenomenon-based education in the secondary school science classroom?). During the focus group interviews the teachers were asked to make a list of challenges of PBSE specifically for their science disciplines and for PBSE in general. The lists of challenges were discussed in the focus group interviews. Challenges collected from the observations and the one-on-one interviews were also added to the discussion when necessary.

Data collection and analysis resulted in many challenges from which four were chosen to elaborate on, since, these challenges were frequently mentioned or had non-expecting outcomes.

4.4.1 – Time and timing

In 6 out of 9 one-on-one interviews the teachers mentioned that time is one of the biggest challenges in PBSE, time for preparing the lessons as well as for conducting the lessons. 3 of the 9 teachers did not mention time as a challenge during the one-on-one interviews, however, 1 (O2) of these 3 teachers did mention time as a big challenge in the OBS focus group interview. Especially, O2 mentioned that interdisciplinary teaching takes more time to prepare: "Challenges in interdisciplinary teaching are the personalities of teachers and the relations between them. When you don’t have a great relationship, it takes more time and energy from the school and from the teachers to work interdisciplinary. When you know each other well that is easier.” 4 of 9 teachers especially mentioned that preparing PBSE is time-consuming: “The preparation time is more then on a normal school. I use three hours every day to prepare for the next lesson” (O1). The 2 other teachers who did not mention time as a challenge for PBSE in the one-on-one interviews did not mention time as a challenge in the focus group interviews either. 3 teachers (including O2) discussed in the focus group interview that time was an important challenge in PBSE: “It is an important challenge to plan and get (in the schedule of the lessons) enough time to go on field trips.” (S6)

In 27 of the 35 observed lessons it was also apparent that the lessons lasted longer than a normal lesson (at SHJ and OBS one normal lesson was 45 minutes). These 27 lessons lasted between 95 and 240 minutes. Only 8 lessons lasted for the normal 45 minutes. 5 of these 8 lessons were lessons in which the teachers only instructed and posed and answered questions, and where the students did not carry out assignments or exercises during these 5 lessons (in all other lessons, there was some kind of exercise or assignment during the lesson).

Besides time for preparation and lessons, 3 teachers also mention in the one-on-one interviews that finding the right timing of the lessons was a challenge. For example, S4 said that beekeeping is mostly interesting for the students in summer, since, the bees do all the work then: “It is unfortunate that the students are on holiday in the summer and that the internships are planned before summer so they [the students] cannot see the bees work.” S2 and S3 also mentioned timing being a challenge, for example, with soil management in the winter, it is not possible to work with the soil when the soil is frozen. S2 and S3 had to change the planning of the lessons when the soil was frozen: “When all is frozen, you have to change your lessons or schedule another lesson in that time.” (S3)

4.4.2 – Finding suitable phenomena

Another challenge was finding a suitable phenomenon. 8 of the 9 interviewed teachers mentioned that finding a suitable phenomenon was a challenge in teaching PBSE: “It is difficult to find the right phenomenon because you have to construct a situation and the phenomena should fit in that and be part of the whole” (O3). 1 teacher did mention that phenomena were important to start the lesson with. However he did not mention that finding a suitable phenomenon was a challenge. S3 mentioned in the one-on-one interview that it was especially hard to find phenomena that connects to all the students as all students have different ways of preferred learning and have other interests.

In conclusion, the three most important challenges in PBSE were time, timing and finding a suitable phenomenon. Not all teachers mentioned all three challenges in the interviews, however, no specific questions were asked regarding challenges teachers did not mention. In addition, some teachers presented solutions in the observations or in the one-on-one interviews. The solutions presented by the teachers are discussed per challenge in Chapter 5.

5 – Conclusions & Discussion

The previous chapter presented the results on this masters' thesis. This chapter combines the results and present solutions for the challenges found in the previous chapter. The results presented in the previous chapter are this chapter linked in to the literature from Chapter 2. This chapter also contains a critical discussion on the research, the data collection methods and analysis applied in this thesis. The chapter ends with advises on future research regarding PBSE and a plan on how to get the information from this research to teachers.

5.1 – Conclusion and recommendations

In this chapter, the results from Chapter 4 were combined, presented and linked to the outcomes of Chapter 2. Results from the data collection of the sub-questions create the background for answering the research question: What are the main challenges for applying phenomenon-based education in the secondary school science classroom? The four most important challenges for PBSE in the classroom are: time, timing and finding a suitable phenomenon. Possibilities to encounter the challenges provided by the teachers are also presented in this chapter.

5.1.1 – Challenge: Time

The outcomes of this master's thesis show that time is one of the biggest challenges for PBSE. When teaching PBL and EL, time also is a challenge (Table 1, Chapter 2). However, interesting is that literature does not show that time is a challenge for IBSE. A reason why PBL, EL and PBSE are time-consuming might be that the focus of all three approaches is on experiencing and learning skills.

Possibilities for encountering the challenge 'time' were presented, for example, in the observations. In 1 of O1's lessons the class went on a field trip. The field trip expanded the regular school hours. The reason why they could go on this time-consuming field trip was because this particular class had already finished the English class and, therefore, would normally have the day off when the rest of the school went on field trips in the English lessons. Instead of the students getting the time off, O1 rather used the day the go to a water power plant. This example shows that it is possible to use more time than the school has planned for lessons. However, teachers have to communicate with the board of the school where and if they can use more time for field trips or other time-consuming activities.

5.1.2 – Challenge: Timing

Another important challenge for PBSE is timing. Table 1 does not mention 'timing' as a challenge for PBS, EL or IBSE. However, both PBL and EL mention the challenge of finding authentic environments. To go to authentic environments is be a challenge that can be categorized under timing. For example, it is not possible to experience rain outside when the sun is shining, or to sprout a seed when it is freezing outside. Furthermore, other literature mentioned in Chapter 2 says that it is important for PBSE to go to the phenomenon or let the phenomenon come to the students, similar to going to an authentic environment, going to the phenomena can also be categorized with the challenge timing.

This thesis shows that challenges regarding holidays and schedules of other courses are challenges with regards to timing. For example, the students are observing a specific animal for a year, however, when they went on holiday for 2 months in the summer they missed the observation of the animals.

Different possibilities to encounter the timing-challenge were posed during the one-on-one interviews. For example, to plan the lessons that does not depend on weather or environment (like theoretical lessons or lessons that give the students background knowledge on subjects) on rainy days or in the winter so the lessons that depend on, for example, warmth can be planned in spring or autumn. A possibility for the challenge of timing in other courses and holidays is one that is not easily solved. S5 advised to talk to the board of the school and explain the problem and ask them to find a solution together.

5.1.3 – Challenge: Finding suitable phenomena

Chapter 2 elaborates on that it is very important for PBSE to have the focus on learning through phenomena, moreover, Chapter 4.1 mentions that 'introducing the subject with a phenomenon that connects to the students life world' is an important characteristic of PBSE. In Chapter 4.4 'finding suitable phenomena' is discussed as one of the most important challenges of PBSE in practice. However, phenomena were not used in all lessons, reasons for not using phenomena were tests and working sessions. Therefore, using phenomena in the classroom is important in PBSE, however, it is challenging to find suitable phenomena. This challenge is similar to challenges explored in IBSE, PBL and EL respectively (Table 1): to find and design inquiries that include all concepts and increase the students curiosity and motivation for learning, to find suitable problems and to facilitate the connection between science and the students personal experiences. Additionally, characteristic of suitable inquiries for IBSE (Table 1) are similar to some of the characteristics of PBSE (Chapter 4.1): the phenomenon and the inquiry should both contain all scientific content and increase the motivation of the students for learning.

Phenomena were not used in all observed lessons. One reason for this could be that teachers mention that it was a challenge to find suitable phenomena for the students, since, every student has his or her own interests. When the classes get bigger it is especially more difficult to match the interests from all the students. The teachers mentioned that is specifically hard to find phenomena to explain theoretical content. O2 found a solution for teaching theoretical content in a way the students are engaged and motivated for learning: O2 used historical phenomena, for example, how researchers did their research on the subject in the past.

Answers on sub-question 3 (Chapter 4.3) show that for some scientific disciplines it is easier to find suitable phenomena then for others. Biology or chemistry related disciplines are easier to find suitable phenomena for then math and physics, since, the student already know a lot of phenomena related to biology and chemistry, for example, their own bodies or the food they eat.

A possible way to encounter the challenge ‘finding suitable phenomena’ was mentioned, for example, by S2 in the one-on-one interview: “it is easier to find suitable phenomena when you know the students”. S2 advises to get to know the students as fast as possible by, for example, going on a trip together and talk to the students while taking a hike, working outdoors on assignments or playing games in teams. S3 agrees with S2 that it is easier to find suitable phenomena for the students when you know the students, since, you know what motivates them and what they are interested in.

5.1.4 – Motivation

Finding an engaging and motivation phenomenon for students for learning is one of the challenges presented by this thesis. Teachers mention that it is important for the students to be able to relate to the phenomenon and that the students are more motivated for learning when the students can identify with the phenomenon. Chapter 2.4 mentioned that students motivation becomes more toward intrinsic motivation when the students are able to identify the phenomenon with their lives and when they understand the meaning of the phenomenon. Finding a suitable phenomenon in which the students can identify themselves and understand the meaning of it regarding their lives, therefore, is both agreed on by the results of this thesis and the literature as an important feature of PBSE.

From the three features necessary for self-determined learning mentioned in Chapter 2.4 (relatedness, autonomy & social contextual conditions that supports the students' feelings of competence) relatedness is present in PBSE in the characteristic of PBSE 'the phenomenon has to connect to the students' life world' (Chapter 4.1.2). The characteristic of PBSE 'students should learn by themselves in their own preferred way of learning' (Chapter 4.1.3) contributes in achieving autonomy. Autonomy is achieved by the students being able to choose the way they want to learn themselves and the way they think they learn best. In this way, the students have a responsibility for their own process of learning. The competence 'implementing students ideas in the classroom' (Chapter 4.2.1) contributes in achieving social contextual conditions that supports the students' feelings of competence. Since, the teachers listen to the students ideas and implements the ideas in the lesson, the students might feel acknowledged in their ideas and the students feel more competent then when the teachers always would say that the ideas are not good enough or will not work beforehand.

In conclusion, the results of this thesis show that PBSE in the range of this thesis provides all three features for self-determined and intrinsic motivation, the results of this thesis did not show that the students were indeed intrinsically motivated, however, to explore the motivational style was also not the focus of this thesis.

5.2 – Discussing the methods of data collection

This master's thesis aimed to answer the following research question: what are the main challenges for applying phenomenon-based education in the secondary school science classroom? However, there are some limitations on the methods of data collection and analysis that have been used in this master's thesis. For example, the focus of this research was only on PBSE and not on other educational approaches, since, focusing on other approaches would take too much time and my personal interest was on exploring PBSE and its challenges in practice. Since, this research did not compare different educational approaches, it does not conclude on the results being specific for PBSE or for teaching in general.

A very important limitation in this master's thesis also was that only one researcher carried out the data collection and analysis which decreases the reliability greatly due to a low inter-rater reliability. In addition, the observations conducted for this research was always based on the interpretation of the observant. When more researchers conduct observations on the same lesson, the inter-rater reliability would increase.

When writing this thesis, it was apparent that data on teachers' in-depth knowledge in the collected data on what the teachers think and why they, for example, did not use phenomena in every lesson was lacking. This lack of in-depth knowledge could have been solved by asking the teachers specifically about activities they did not conduct, for example, competences of PBSE they did not mention. The one-on-one interviews and the focus group interviews were set-up in a way where the teachers could openly answer the questions. However, this means that it could happen that the teachers forgot to mention, for example, characteristics of PBSE that they found important only just forgot to mention. When questions regarding, for example, characteristics that were mentioned in previous interviews were asked, the results of this thesis would possibly be different.

5.3 – Possibilities to encounter challenges of PBSE

This thesis' research was focused on the challenges of PBSE and not on the possibilities to encounter these challenges, therefore, only a few possibilities are mentioned earlier in this chapter. In order to find valid and reliable possibilities for encountering the challenges presented in Chapter 5, more qualitative research is necessary. For example, by conducting literature research on the challenges and possibilities from teachers when teaching IBSE, PBL and EL, mentioned in Chapter 2. The challenges mentioned in Table 1 are similar to the challenges resulted from this thesis' research, therefore, more challenges found in literature might also be similar for IBSE, PBL, EL and PBSE. Possibilities to encounter challenges that resulted from literature research to IBSE, PBL and EL can be tested to see if these possibilities also work with PBSE and its challenges.

5.4 – Future Research

This master's thesis was focused on the challenges of PBSE in secondary schools. However, there still is little empirical research conducted on the learning outcomes of PBSE in secondary schools. Research on learning outcomes of PBSE in secondary schools is of great importance for PBSE to be used more often in secondary school situations. Therefore, quantitative research on the comparison of PBSE to other educational approaches, regarding learning outcomes, is important.

More research on the competences of teachers when using PBSE in the classroom can help (inexperienced) teachers. For example, when they want to use PBSE and do not know where they should start or what they need. In addition, more research is necessary on challenges of PBSE in the classroom. Specific research can be conducted with the research design of this master's thesis, however, it needs more researchers to eliminate researcher bias and teachers and schools to increase the reliability. Research over a longer time span is necessary also be conducted to see if the teaching methods of the teachers and the motivation and engagement of the students differs over a year.

This thesis also did not focus on the different forms of motivation with regards to PBSE. To explore if PBSE increases the form of motivation to intrinsic motivation or even to more autonomous forms of extrinsic motivations (Chapter 2.4) more research is necessary on the relation between different motivational forms and PBSE.

Overall, the question is also whether SJH and OBS were representative schools for teaching PBSE. This questions remains unanswered, since, this thesis only had OBS and SJH as sites. Research on more schools where PBSE is practiced can be used for exploring representativeness for PBSE. The characteristics, competences, similarities and differences between disciplines and challenges presented in Chapter 4 can be used as a background for further research regarding PBSE.

5.5 – How to get the results of this master's thesis to the teachers

The answers on the research question and the sub-questions of this master's thesis are intended for secondary school teachers. Bringing the results from this thesis to the secondary school teachers is a challenge, since, for as I know, secondary school teachers are going to search the thesis database of UU or NMBU before designing their education. Therefore, a different way to get the results of this theses to the secondary school teachers is necessary. Within the process of my master, I have the amazing opportunity to do two internships on secondary schools. In these internships I will explore the possibility to use PBSE in the classroom. Teachers will be informed by me on PBSE and the results of this thesis and when the teachers are willing, we will together make plans to introduce PBSE in the schools. This thesis did not research if PBSE enhances the learning results or effects the motivation and engagement of the students for learning, therefore, it is necessary to conduct more research. I will spread the word about PBSE and hopefully teachers will start talking about it so more people know of PBSE and more research can be done on PBSE.

7 - Bibliography

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8 - Appendices

Appendix I: Classroom maps

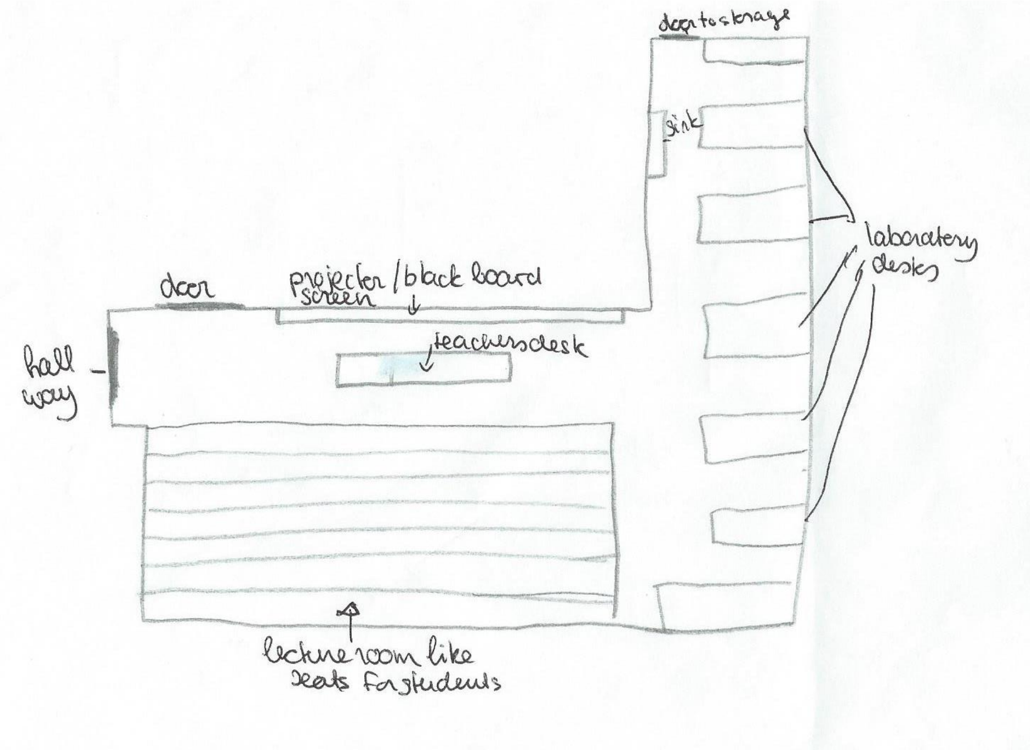

Figure 5 OBS classroom

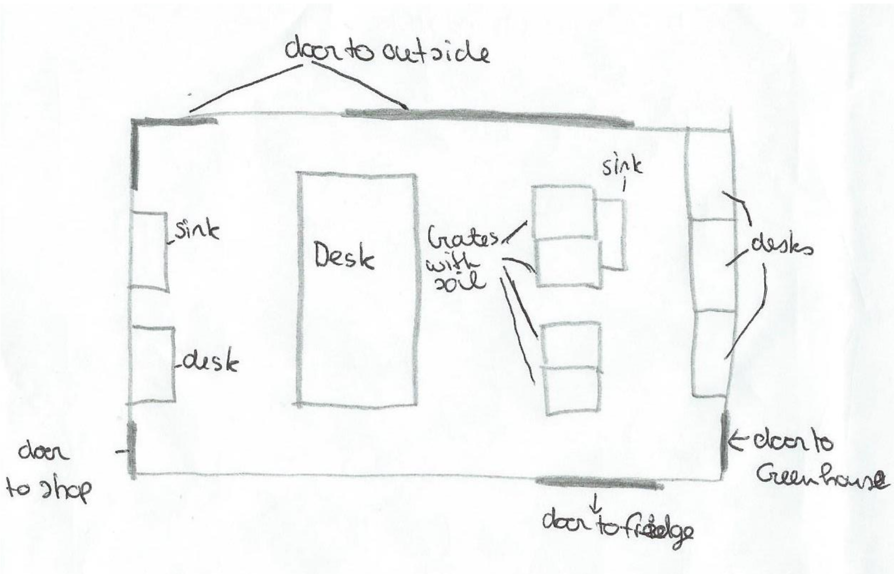

Figure 6 SJH greenhouse classroom

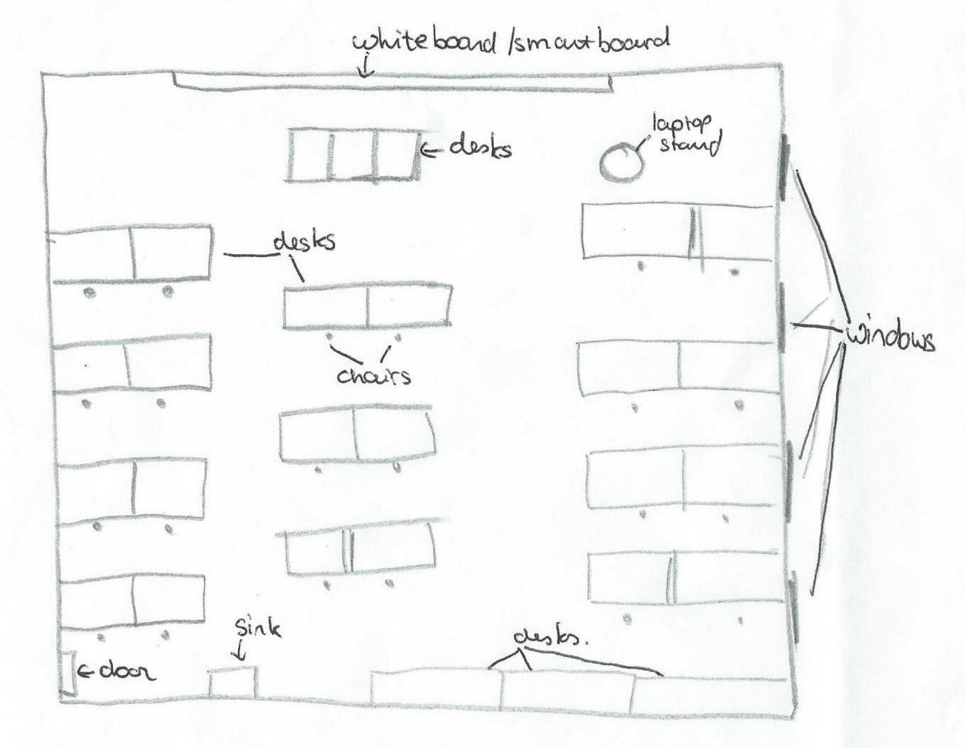

Figure 7 SJH VG2 classroom

Appendix II: Case study observation focus points

1) What characteristics of PBSE is the teacher using? In what way?
2) How is the schedule of the lesson?
3a+b) What kind of exercises are used in today's lesson? Are they working in groups or individually?
4) How does the teacher introduce the phenomenon and what is the phenomenon?
5) What motivates the students to do the exercises?
6) In what way do the students work with the phenomenon?
7) How do the students investigate the phenomenon?
8) How do the students react on the way of teaching?
9) What kind of interaction is there between the teacher and the students?
10) What kind of interaction is there between students?
11) What actions/competencies is the teacher using during teaching?
12) What are the challenges in teaching for the teacher? In general and specific on his/her field of expertise?

Appendix III: Interview guide (SJH)

General information

I will be using an audio recorder to record the interview. Video recording won't be necessary because the interview will be about experiences and thoughts of the interviewee and not about actions. The experiences and thoughts will be acquired by questions and verbatim answers. No physical activity is required. I will bring a white paper and pencils for the interviewee, for if he wants to express himself through drawings or write things down. I will also bring enough paper to write on for me as Open Space. In this open space, I will write things I want to come back to during the interview and I write down other important things and afterwards how the atmosphere of the interview was.

The interview will take maximum an hour. The interview is divided into two parts, the first part is about the interviewee itself and will provide information about the interviewee as a person. The second part is about gaining knowledge to answer the sub-questions.

Preparation on site

- The room should not contain other people except for the interviewer and interviewee.
- There cannot be unwanted noises or other distractions in the room or in the area.
- Make sure the laptop is on recording and has the power plugged into the wall, so that won't interrupt the interview.
- Make sure that the time is visible, so you can track the time and the interview will take the time it was planned for.
- Make a note for on the door with 'do not disturb – interview'.
- Phone off or in another room
- Provide paper and pencils

Tips from evaluation last time

The most important reflection point is the one about not finishing sentences of the interviewee. I need to work on this when I want my master's thesis to work out. When I finish sentences of the interviewees, I will not receive the data I intend to receive with the interview. A second tip for future interviews is to use a lot of time and energy to write the interview guide. For the trail interview, I used a lot of preparation time and I gained benefits from this complete preparation. The last important tip for future interviews is that I need to write down the things I want to use in the summary of the interview and I need to always sum up the interview together with the interviewee so we both can check if we understood what we talked about and the interviewee can use this time to reflect on his/her words and maybe add things to the interview or explain his/herself further.

Introduction

Thanks for being here and using your time to help me with this interview and my research. For two weeks I have been observing your classes and that provided me with a lot of informative data. I have not yet analyzed the data, however, I can, at the end of this introduction, mention some of the things I will be using for my research. We already had some talks about the results of the master's thesis and I will send you the results and the final documents. I hope I am able to come back after finishing the thesis to present it to you and other people here in Ås and I can try to come here too, but I have to see if that is possible.

When I was making this interview guide, it came to me that you probably don't know anything about me, so I will introduce myself and the reason why I am doing research here shortly. I am Lise Berghuis, 24 years old and I have a bachelor degree in Biology and am doing my master in the Netherlands. The master is called Science education and communication and has two tracks. The one I chose focuses on researching education. That is why I am here. The other track is the teachers track and after I finish this track, I will continue with the teachers track. My bachelors thesis had authentic learning in biology lessons as subject and through this I became interested in these kind of educational approaches. When I had to choose a subject for my master's thesis I knew that I wanted to do research on PBSE. I wrote a research proposal and after a long search I had a place in Ås to work and Edvin Østergaard as a supervisor. Edvin and I chose two schools for me to conduct case studies. The reason why we chose SJH is because Edvin knows Aksel pretty good and Edvin thought this might be a good site to observe PBSE in practice.

My research is about Phenomenon-based science education (as you might have guessed) and with a focus on the challenges that teachers have when they want to implement this educational approach in their teaching. The thesis is also about the opportunities PBSE has in learning and teaching. If you want to, I can tell you my definition of PBSE at the end of the interview. The reason I do not tell you now is that one of the questions in the research focusses on the perspective of the teachers on PBSE, in this way, I am interested in the personal thoughts of teachers about PBSE.

For this research, a school which teaches traditionally, would not provide me with usable data. This is why we chose OBS and SJH. There are two big differences (at least for what I have seen now) between these schools. The first is the place: SJH is in a rural area and OBS is in the middle of Oslo. The second big difference is that on OBs the students are being prepared for university and at SJH they are prepared for a job in ecological agriculture, is this right?

The interview will be in two parts. The first part will be about you so I will receive some personal information, for example, about your background with regards to education. The second part will focus more on your experiences and thoughts as a teacher. The interview will be approximately one hour and I will record the interview if that is not a problem for you. I will be the only one who will listen to the recordings. Is it okay if I make you anonymous? I brought some pencils and paper for if you want to express yourself through drawing or if you want to write something down.

Interview questions

1. What is your age
2. What is your background (with regards to education)
3. How many years do you work on SJH?
4. Was SJH the only school where you worked? Can you tell me about the schools (location/how many kids)
5. What courses do you teach?
6. Do you know what PBSE is? What is your definition of PBL in science education?
7. What are your personal thoughts on PBSE?
8. Can you explain if and in what way you work with PBL in science education?
9. Can you tell me how you prepare your classes?
10. Why did you chose to work with PBSE?
11. What do you think are the abilities/characteristics teachers should have when successfully working with PBSE?
12. Have you worked in other situations with PBSE?
13. When he does not work with PBSE: Do you have the desire to work with PBSE?
14. Have you experienced challenges with teaching through PBSE?
15. Do you think these challenges are specific for your discipline(s)?

16. If he taught different disciplines: Are there differences between teaching PBSE in the different disciplines?
17. Do you think there is a difference between working with PBSE in the different levels of students (1st vs 2nd vs 3th grade)?
18. When on other schools: which are the differences in teaching PBSE in the different schools?
19. Have you worked with other educational approaches? Which?
20. Did you encounter the same difficulties or similarities when using/implementing these other approaches?

Ending

Thanks for your time and energy and helping me with this interview. Give a short summary of the important things: for example → the heaviest argument for choosing PBSE or the most important challenges and opportunities for PBSE. Ask if I am right about this.

Do you have questions or comments on the things you said or I have said or about other things? Do you have tips or tricks for me as an interviewer?