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The Implementation of Inquiry-based Teaching

An Assessment of Newly Educated Danish Science Teachers Implementation of Inquiry-based Teaching

Jakob R. Holm
Kandidatspeciale – Geografi

Vejledere: Robert Harry Evans og Lene Møller Madsen

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Master's Thesis

Jakob R. Holm

The Implementation of Inquiry-based Teaching

An Assessment of Newly Educated Danish Science Teachers Implementation of Inquiry-based Teaching

Supervisor: Robert H. Evans and Lene M. Madsen

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Abstract

Throughout the past decades, inquiry-based teaching has been subject to much research that has documented its effectiveness. In spite of this, the teaching method remains largely unused in Danish science classrooms, as many teachers haven't been properly educated in, how to apply it in their teaching practice and perceive it as time-consuming, and difficult to control, as a result of its open and student centred nature.

In order to understand, if this also applies to newly educated science teachers, who have been properly introduced to the teaching method at the course 'Advanced Methods of Teaching Science' at the University of Copenhagen, I have studied how six newly educated science teachers understand and perceive IBSE, and in addition observed how they employ it into their teaching practice.

I have collected data in classroom observations and interviews, and I have, among others, found that the participating teachers generally have extensive knowledge of IBSE, which they perceive as a valuable pedagogical tool that they frequently employ in their teaching. The way it is implemented varies, based on factors such as the academic level of the students, the classroom chemistry and the individual teaching style of the teacher, but in general, the participating teachers always design their inquiry-based lessons with the 6F-model as an underlying template.

However, In spite of the extensive understanding and positive attitudes to inquiry-based teaching, the teachers involved in this study, often experience challenges related to, especially the time-consuming nature of IBSE, and how to provide feedback to their students, why I conclude that more attention must be given to address these issues at the 'Advanced Methods of Teaching Science' course.

Preface and Acknowledgements

As this thesis concludes my studies in Geography and History at the University of Copenhagen, where I have worked for five and a half years, with the goal of achieving a career in teaching, it was always an easy decision for me to make, when I chose to write my thesis at the Department of Science Education.

The central idea of this study, to investigate newly educated science teachers' perceptions of and use of inquiry-based teaching, occurred to me, when I was talking to a geography teacher about his perceptions of the teaching method, during the 'Advanced Methods of Teaching Science' course, where I myself have been a student.

During the conversation, I realized that even though inquiry-based teaching, as documented by much research, is an effective method of science instruction, teachers sometimes struggle to implement it into their teaching practice for various reasons. In this thesis I attempt to get a deeper understanding of these struggles and shed light on how newly educated Danish science teachers apply inquiry-based teaching into their teaching practice.

As the research for these questions, obviously would have been impossible without the help of the teachers, who volunteered to be interviewed and observed, I would especially like to thank them for giving up their own time to help me.

Furthermore I wish to thank the people who have assisted me in various different ways, throughout the entire process of working on this thesis, these people, among others, include my two supervisors Lene Møller Madsen and Robert Harry Evans who have guided and encouraged me for the last couple of months, but they also include my fellow thesis students, at the Department of Science Education, who have provided practical and academic aid for several chapters of this report.

Finally I wish to thank my family, and especially my girlfriend, for taking care of our new-born child and for letting me sleep through the nights, so that I have been able to express myself somewhat coherently and accurately.

Thank you all
Jakob Rasmus Holm
June 2018

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1. Introduction

Inquiry-based teaching (IBSE: Inquiry based science education)[1] is an instructional method that is founded in a constructivist tradition and used in science classrooms around the world.
It can be considered a student centred form of teaching, as students, in inquiry-based lessons, explore scientific questions, typically by experimenting, while the teacher guides them in the right direction, without interfering or taking direct part in the exploration.

Throughout the past decades, IBSE has been subject to much research that has documented its effectiveness, but in spite of this, it remains largely unused in science classrooms, among other things because many teachers perceive it as time-consuming, and difficult to control, as a result of its open and student centred nature.

As I, in this thesis, study newly educated Danish science teachers' perceptions and understandings of the teaching method and investigate how it is introduced in practice, this thesis is meant to add to the body of literature in science education, which seeks to improve science teacher education and professional development.
I use a combination of qualitative and quantitative methods to get insights from the teachers themselves and from their classrooms. My approach has been, to interview six science teachers, who teach different subjects at various academic levels, in order to learn about their perspectives. Additionally I have observed three of these teachers' teach a module at their respective schools, in order to understand how inquiry-based teaching takes place in practice.

I have then submitted the data from my interviews and observations, to a thematic and a descriptive analysis, respectively, in order to answer my research questions. In this thesis, I present these answers and the work that led me to them.

I begin by contextualizing inquiry-based teaching, by presenting central aspects of the teaching method and reviewing its theoretical roots and historical development. This is followed by a presentation of research relevant for this study, where I among others focus on positive and negative aspects of the teaching method and case studies that explore how newly educated science teachers implement IBSE in practice. The content of the first two chapters are meant to form the background of my research questions, these are presented as

[1] I use the acronym IBSE and the term 'inquiry-based teaching' interchangeably to refer to the teaching method in this thesis, as both are common in international (Harlen 2010; Lawson 2010; Llewelyn, 2013) and in Danish research. (Kruse 2013; Østergaard et al 2010).

Chapter 4. The methods of my study are described in Chapter 5, and in Chapter 6, I go through my analysis and my results. In Chapter 7 I discuss my findings, before I provide a conclusion and give suggestions for future perspectives in Chapter 8 and 9.

2. Background

In order to examine how educators use and experience inquiry based teaching, it is important to understand exactly what it is. Therefore, this following chapter seeks to contextualize this study, by explaining some of the many aspects of the teaching method.

To provide a basic understanding of IBSE and its implementation, the first section explains its nature and explores how it functions in practice. In the second section I explain constructivism, which is the theoretical framework for IBSE. This is followed by a section, in which I briefly review some of the original thoughts and teaching strategies that have inspired to the creation of IBSE.
In the fourth section, inquiry-based teaching with a focus on learning models, such as the 5E and the 6F-models, are thoroughly reviewed. And finally in the fifth section, I explore how learning in circles can lead to a higher level of scientific literacy.

The nature of Inquiry-based teaching

Every educator has a unique way of teaching; consequently, multiple methods and teaching strategies are used in science classrooms, museums and schools, ranging from cookbook exercises, direct instruction, multimedia-presentations and textbook instruction to inquiry-based teaching.

Each of these methods has different benefits and limitations. As an example, teaching that uses direct instructions from the teacher and textbooks, tend to focus on students' acquisition of factual knowledge (Bass et al. 2009). Consequently, this kind of teaching has the potential to cover a large body of information, often directly related to a given curriculum, but it also tend to focus on memory and learning answers, rather than exploration and critical thought (Reaume 2011).
Conversely, an additional aim of inquiry-based teaching is that students learn the correct scientific methods and language (Gormally, Brickman et al. 2009), it is designed to engage students through group work and experiments, in which students get to practice their scientific understandings.

Overall, there are many definitions of IBSE, but in this study I have chosen to use the definition given in the National Science Education Standards:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations reviewing what is already known in light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC 1996 p. 23).

In other words, in inquiry-based lessons students are required to solve problems by using scientific methods (Spronken-Smith and Walker 2010), but as the students do not already have well developed skills of observing, collecting evidence, making predictions, testing possible explanations and interpreting findings, they not only develop an understanding of the scientific subject they are working with, they also get hands on experience, increasing their scientific literacy in the process, which is one of the most important arguments of IBSE (Frisdahl 2014; Harlen 2004). IBSE is thus thought to provide students with a deeper understanding of a given science related subject, as the knowledge developed is based on both the methodological and the conceptual understandings of natural science (Bass et al. 2009; Marshall and Alston, 2014; Reaume 2011), which fits well with the overall goals for Danish science teaching, as teachers, among others, are expected to teach about, for instance, scientific reasoning and argumentation and the role of experiments in science[2].

Inquiry-based teaching in practice

Because of its width, there are many ways in which IBSE can be practiced: "It is not a program of study, nor a scheme of work, or a curriculum model" (Harlen 2004 p. 6). Therefore inquiry-based teaching can take on multiple forms in practice, varying from short investigative sessions, which might fit into a single module, to month-long activities (Crawford 1999).

However, inquiry-based teaching is usually structured around a student's independent exploration of a scientific issue. The exploration, is scaffolded by the teacher who provides materials and feedback and in general facilitates the activity without providing the students with any answers. The most significant difference between IBSE and traditional teaching, is that the students are allowed to work with the problem before the teacher uses their new and partial understandings to create factual knowledge which is new to the students (Nielsen 2017).

Even though there are standards that formulate suggestions and goals for IBSE teaching, as the purpose statements made by the ministry of education, it is ultimately up to the individual educator to design the teaching to fit these goals. As a result the individual inquiry-based lessons do, in practice, differ due to teachers conceptions of inquiry and factors such as teachers own education and knowledge, the age of the students, the academic level of the students, classroom chemistry, availability of science equipment etc. (Keys and Bryan 2001).

[2] As an example the teaching-plan for the scientific introductory course at C-level (Upper secondary school) is attached as Appendix A

In fact, Harlen (2004) suggests that different modes of implementation not only are inevitable, but even desirable, as different situations to a higher degree will reflect the real world. Furthermore the diversity of IBSE has the potential to invite teachers into using inquiry in ways that match their own beliefs and teaching styles (Keys and Bryan 2001).From this perspective, what makes teaching recognizable as inquiry-based, is ultimately the character of activities taking place in the classroom. Table 1 summarizes some of the key features that make a lesson inquiry-based.

Table: 1 Characteristics of inquiry-based science education. Based on Harlen 2004; Østergaard, Sillasen et al. 2010

Characteristics of Inquiry-based science education
1. **The students are engaged by scientific questions** The nature of IBSE requires students to work in a scientific way, creating their own hypotheses about the natural world, materials, objects or events. This can be done individually or in collaborative groups making it possible to share ideas, formulate hypotheses and construct understanding together.
2. **Formulation of hypotheses** Starting with their existing knowledge, including their exploration of the problem, students formulate potential solutions in order to solve a problem.
3. **Testing** To imitate the scientific methods, the students must consider how their hypothesis can be tested and answers may be found through investigation. This requires them to select, organize and present their data in accordance to their hypotheses.
4. **Conclusion, validation and contextualization** The students present their solutions and seek to validate their answers through other sources. In order to extend their newly found scientific knowledge, the students must apply their findings and skills to other contexts and situations.

Throughout an inquiry-based course, it is the teacher's responsibility to guide and support the student's activities by providing scientific material, asking open-ended questions to stimulate understanding, and when necessary, help students with planning, so that hypotheses and ideas are properly tested. But it is the students who must do the exploring.

In this context, it can be argued that the student centred nature of IBSE, has the potential to get students to take ownership of their experiments and even capture and maintain their motivation for working with natural science in the future (Frisdahl 2014) The teacher's role is thus significantly changed in a student centred inquiry-based science lesson, as he or she goes from being in control of the students' activities, to supporting the students, when they formulate research questions that they themselves can work on.

There are, however, as mentioned, different factors that decide how inquiry based teaching is structured in the individual classroom, as parameters such as the student's academic level, the subject's complexity and the students' ability to work independently, can influence the degree of openness of the inquiry-based activity. The teacher can thus, based on the environment in which he or she teaches, adjust the level of inquiry, by increasing or downgrading the amount of decisions that the students should relate to, during the session. This is described by among others Trnova and Trna (2012) and Colburn (2000), who distinguish three different levels of inquiry (Table 2).

Table 2: Three levels of inquiry from Trnova and Trna (2012 p. 12)

Three levels of inquiry-based teaching
Structured Inquiry The teacher provides students with a hands-on problem to investigate, as well as the procedures, and materials, but does not inform them of expected outcomes. Students are to discover relationships between variables or otherwise generalize from data collected. These types of investigations are similar to those known as cookbook activities, although a cookbook activity generally includes more direction than a structured inquiry activity about what students are to observe and which data they are to collect.
Guided Inquiry The teacher provides only the materials and problem to investigate. Students devise their own procedure to solve the problem.
Open Inquiry This approach is similar to guided inquiry, with the addition that students also formulate their own problem to investigate. Open inquiry, in many ways, is similar to real world science.

In summary Inquiry-based teaching can be understood as a superordinate term that includes various different ways of teaching, in which students follow and imitate methods and practices similar to those of professional scientists, with the intention of creating their own knowledge. The teaching-method is student centred and designed so that students get hands on experience with the scientific world and improve their scientific literacy, while the teacher facilitates the learning by scaffolding, assisting and providing feedback.

The Origin of Inquiry-based Teaching

After having explained the nature of inquiry based teaching, the following section examines constructivism, which is the theoretical framework from which IBSE derives. This is followed by a brief review of the historical development of inquiry-based teaching and the learning-models that have grown to be a central part of the implementation of IBSE in science classrooms around the world (Østergaard, Sillasen et al. 2010).

The Constructivist way of Learning

In contemporary science education, constructivism has been a major theoretical influence, inspiring many new methods of science instruction, including IBSE (Matthews 1994).

One of the central principles of constructivism is that every human being searches for, negotiates and constructs meaning from the world around us, by reflecting on our everyday experiences (Llewellyn 2013). Knowledge is therefore, in a constructivist point of view, not passively received, but actively built up by the cognizing subject. In this perspective, learning is not only an active, but also a highly personal process, as new information is managed differently from person to person, based on prior individual knowledge and experiences.

Jean Piaget who was one of the founders of constructivism, formulated the central concept mentioned above, that all knowledge is created and adapted through a lifelong process of interaction with new experiences and situations (Andersen & Krogh 2017). Furthermore, he argued that the knowledge of a person is structured as figurative or operative mental schemas, related to either actions or consequences. When a person, in this perspective, encounters a new situation, his existing mental schemas come in to play, and knowledge is shaped through a combination of processes known as assimilation and accommodation.

Assimilation can be understood as a process, where new experiences that fit into already existing mental schemas is added, without the schemas being fundamentally changed. Whereas in the process of accommodation, the mental schemas are altered; modified or changed to accept or fit the newly perceived knowledge (Ibid)

The adaption of new knowledge then occurs, because the individual encounters phenomena that cannot be fitted into his already existing cognitive structures. In these situations, the individual experiences a state of disequilibrium, which can only be solved if the person adjusts his already existing cognitive structures to accommodate the new situations (Llewellyn 2013; Andersen & Krogh 2017).

Social Constructivism

Even though learning, as stated, is a personal process, it should not be understood to mean that it occurs independently of others. This was theorized by Lev Vygotsky, who came to be of huge importance for the social constructivist movement, which can be seen as an important corrective to classical constructivism (Winsløw 2009)

The idea that the cognitive development of a person, to a high degree, is driven by social interactions is fundamentally different from Piaget's ideas, in which the cognitive development primarily was considered to be an individual process. Learning, from a social constructivist perspective, is thus mediated by aspects such as social interactions, which makes it possible for the students to argue, discuss and, in general, use their language, which is considered the most fundamental symbolic learning tool in social constructivism, which is expressed in one of Vygotskys well-known quotes:

"Thought is not merely expressed in words, it comes into existence through them" (Andersen & Krogh. 2017 p. 24).

In extension of this, Vygotsky suggested that the individual student, to a high degree, develops his cognitive understanding, through dialogue with teachers or other students. To illustrate how the process of learning works, he introduced the concept: the zone of proximal development (ZPD).

"The ZPD should be understood as the realm of what is slightly beyond the learner's skill. This is limited on the lower end, by what the learner can accomplish independently, and on the upper end, by what the learner can accomplish through interactions with others, such as peers, teachers or tutors. In the ZPD the learner's actions are 'scaffolded', so that they are able to do more than they were able to do on their own. By practicing this, the learner's abilities grow, pushing the boundaries of the ZPD further outward, and thus learning occurs"(Doolittle 1997 p. 85)".

From the social constructivists point of view, it is thus crucial for the cognitive development of a person, that the teaching is not only based on where the individual student is in his mastery of content , but that it also builds upon knowledge about how much the student is able to develop and accomplish.

In order to describe the teacher's work, supporting the students within the ZPD, the American psychologist Jerome Bruner introduced the concept of scaffolding (Wood, Bruner et al. 1976), in which the central idea is that the teacher supports the student during the learning process, with the intention of helping him achieve his learning goals. Then when the student reaches a self-supporting level of knowledge, these supports are then gradually removed (Ibid).

Various different pedagogical actions relate to the concept of scaffolding, these among others include: providing resources for the student, introducing a compelling task, providing templates and guides, giving advice and coaching.

In relation to this, it is indeed possible to see features from constructivism and social constructivism embedded within inquiry-based teaching.
IBSE is thus structured so that the conceptual knowledge of the learner is created during research, where students in groups negotiate and reflect on observed phenomena and develop their professional language.

Additionally inquiry-based teaching emphasizes the importance of ascertaining the learners predefined knowledge of a subject, in order to create cognitive disequilibrium and optimize learning. This is used in contemporary teaching models exemplified by the 6F model, in which an actual phase has been added that serves the purpose of "uncovering" what the student already knows or thinks about a given subject or topic.

Finally, the teacher's role in inquiry-based teaching is directly comparable to the notion of scaffolding, as it is the teacher who introduces a compelling task and provides materials, but most importantly guides students by giving them feedback, which is a central part of IBSE, because of it's student centred and open-ended nature. Through the process of feedback the teacher can stimulate student learning and ensure the highest possible learning outcome by adjusting the level of scaffolding, so that it fits with the individual student. This does however require much of the teacher, who must have a detailed knowledge of the competencies and opportunities for development for each student.

The Story of Inquiry-based Science Education

After having examined some of the constructivist concepts underlying inquiry-based teaching, this section focuses on how the teaching method has evolved from being principles and ideas to more concrete teaching tools and models.

Even though IBSE as a teaching method, was only introduced in Denmark recently (Østergaard, Sillasen et al. 2010), its core ideas has several historical predecessors and can be traced back, to the beginning of the twentieth century and the work of the German philosopher Johan Friedrich Herbart, who formulated two important principles for teaching, that can still be detected in the methods of inquiry-based teaching today (Bybee 2015).

For Herbart, the primary purpose of education was the development of character, and the process of developing character began with cultivating the student's interest in a topic (Ibid).

In other words, effective instruction was dependent on the students overall interest in the subject being taught. According to Herbart, the way to stimulate this interest was most effectively achieved through social interactions in the classroom, and by letting students get direct experiences with the natural world, by making observations and experiments.

In order to increase the conceptual understanding of the students, it was then essential that the impressions gained from the practical work, was put into relation with the students' prior knowledge and formed into general concepts or principles, which was Herbart's second principle of teaching.

Overall, both of Herbart's principles have influenced contemporary inquiry-based teaching, which also emphasizes the stimulation of the students' interest, the importance of doing practical work and the scientific methodology.

Another influential philosopher of the early twentieth century, was the American academic, constructivist and teacher John Dewey. In his book 'How we think', which was first published in 1910, he acknowledged the ideas of Herbart and proposed, what he thought were five indispensable steps of reflective thinking. These included: (1) Defining the problem, (2) noting conditions associated with the problem, (3) formulating a hypothesis for solving the problem, (4) elaborating the value of various solutions, and (5) testing the ideas to see which provided the best solution for the problem (Dewey, 1997 p. 72).

Although Dewey's indispensible features for reflective thinking cannot be classified as an actual instructional model, it is still possible to detect some important similarities with contemporary inquiry-based teaching and his idea, 'that there is an order of events, that should optimally occur in the process of human learning' and Herbart's thoughts about cultivating the students interest, was eventually adopted by the creators of several contemporary learning cycles (Lawson 2009).

Developing Instructional Models

In 1962 J. Atkin and Robert Karplus, proposed an early edition of a learning cycle that became a source of inspiration for many other models (Lawson, 2009: Bybee, 2015). It was designed to correspond to the way scientist invented and used concepts about the nature and involved three phases: exploration, concept introduction, and concept application (Llewellyn 2013).

The purpose of the exploration phase was to allow students to become interested in the subject at hand, raise questions, gather data and identify points of dissatisfaction with their current understanding.

This was followed by the concept introduction, which was a phase where the data and observations gathered in the exploration phase were interpreted, explained and discussed in the classroom.

Finally, the concept application phase gave the students opportunities to test their ideas, and try out their latest understandings in new contexts (Tanner 2010).

In the mid eighties the BSCS[3] 5E's instructional model was then created. Its author, Roger Bybee and his colleagues described it as a 'direct descendant' of the Atkins and Karplus learning cycle (Bybee 2015), as it contained parts from all three of the abovementioned phases, and in general served the same purpose, to create optimal conditions for the students construction of new conceptual knowledge (Ibid). In order to elucidate the learning cycle, it was divided into five phases, each starting with an E named after what they imply; Engage, Explore, Explain, Elaborate and Evaluate (Ibid).

The engaging phase is thus meant to engage students in the subject and establish their focus. In the Exploration phase students explore and examine concepts and issues. In the Explaining phase, students explain their discoveries. Finally the students newly found understanding of phenomena and concepts are extended through new activities and experiences in the Elaborating phase.

Furthermore, in the Evaluating phase the teacher assess the learning outcomes of the lesson, however, evaluate also refer to the continuing informal evaluation of the students throughout the cycle (Ibid), which is illustrated in Figure 1.

[3] Biological Sciences Curiculum Study

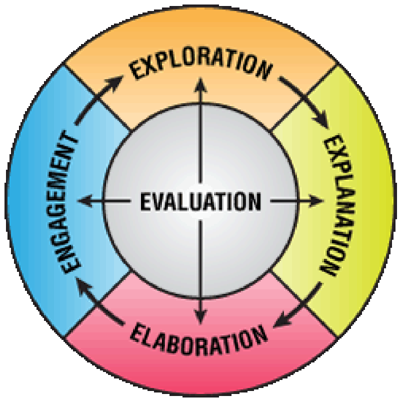

Figure 1: The phases of 5E-model (From A. Berg. 2014)

The 5E model has since been redefined several times by, among others, Arthur Eisenkraft (Eisenkraft 2003), who wanted to emphasize the importance of ascertaining the student's prior knowledge, which can be related to the constructivist way of learning. Therefore, in 2003 he added an extension to the model by splitting the engagement phase into two, Elicit and Engage. Additionally, Eisenkraft also argued for the importance of using the newly added knowledge of the students in other situations, adding, therefore, the Extension phase. The 5E and 7E models were later transformed into a Danish version, named, The 6F-model, at the course Advanced Methods of Teaching Science, at the University of Copenhagen.

The 6F model was created on the basis of, and can be seen as a combination of The 5E and 7E models, and contains the phases: Elicit, Engage, Explore, Explain, Extent and a more fluid formative version of Evaluation, which is called Feedback. During my interviews I learned that all of my informants associated the 6F model, in particular, with inquiry-based teaching. As a result, this study emphasizes the 6F rather than the 5E-model, even though the latter is more often used in an international context.

The principles for the individual phases of the 6F-models are described in the following section.

The 6F Model

As mentioned, the 6F model, like other teaching models, is meant to structure inquiry lessons that often have a high degree of freedom for the individual student (Østergaard, Sillasen et al. 2010). The 6F model is, as shown in Figure 2, circular, as a course of instruction will most likely follow in a closed circle, where the extension phase potentially can initiate a new course (Frisdahl, 2014). The model is dynamic, which allows teachers to use it in different ways, some phases can thus be repeated more than once in a lesson. It should, however once again be mentioned that the phases Explain and Extent must not be introduced before the students have explored a topic.

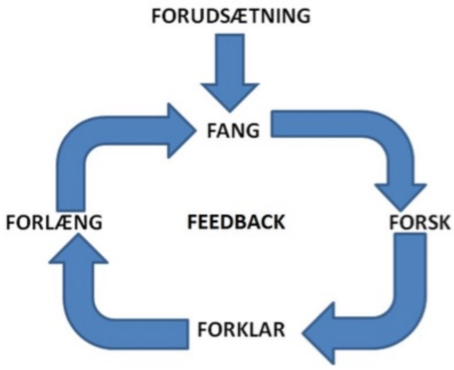

Figure 2: The phases of the 6F-model (From Evans and Madsen 2012)

Even though the Danish 6F-model, to a high degree, looks like the 5E and 7E-models, there is a significant difference in the nature of the feedback being given. As illustrated in Figure 2, feedback is being exchanged continuously throughout the lesson in the 6f-model, changing the nature of the feedback from being summative to formative. This change has been completed, as formative feedback is suitable for an inquiry lesson, as it not only keeps the students going, but also gives the teacher valuable information about the students experiences and general progress, which he can use when scaffolding the learning of the individual student (personal conversation with associate professor at Department of Science Education, Robert Harry Evans). The general principles of the phases of the 6F-model are elaborated on the upcoming pages.

Elicit.

The central part of the first phase of a 6F- lesson is that the teacher ascertains insights about the student's prerequisites related to the subject of the lesson being started. From a constructivist perspective, successful learning is founded in the student's predefined knowledge; therefore it is essential that the questions or exercises are formulated to reveal insights about this. Additionally the phase gives the teacher knowledge of the students' academical level, providing the opportunity to decide whether there is a need for changes or adjustments in the planned course of instruction (Bass et al. 2009; Bybee et al. 2006).

Engage.

The engaging phase serves the purpose of creating a teachable moment by catching the student's interest in the subject, motivating the student to seek new knowledge (Bybee 2015). This can be done with surprising, fascinating and marvellous movie clips, trials, data sets, etc. The elicit and engage phases are closely linked as the engaging phase must be based on, and challenge the previously held assumptions and views of the students “thus creating cognitive disequilibrium” (Ulriksen, Jensen et al. 2013).

Explore

After the student’s interest has been awoken, they must work in a scientific way, exploring, gathering data and formulating hypotheses about the phenomena that they are studying. In this phase the students are responsible for doing the research and developing ideas that the teacher can later relate to institutionalized knowledge (Nielsen 2017). It is, however, as we have seen, possible to modify the openness of inquiry in a lesson, depending on the academic level of the students. There is thus no definite way to implement an explorative phase, which can vary in many ways, based on subject, the teacher's expertise and the available remedies in the classroom (Harlen 2004).

Explain

In the explain phase the students are given the opportunity to share and test their observations, hypotheses and conclusions with their fellow students and the teacher. (Bass et al. 2009: Frisdahl 2014). A central point of the explanative phase is that the discussion is built on the students 'own experiences from the research phase, which gives them an opportunity to express their conceptual understandings and train their scientific language.
This phase is however also meant to interconnect the context-emphasizing and open-ended practical work with the teaching plans and the curriculum, which defines what teachers are supposed to teach in their classrooms. The teacher can therefore introduce institutionalized knowledge, concepts or definitions that relate to the work of the students in this phase (Bybee 2015; Frisdahl 2014).

Extend

In the extending phase, the students newly achieved knowledge is applied in new contexts. The phase is thus designed to challenge and extent the conceptual understanding of the students and provides further opportunity to practice scientific skills and language allowing students to develop a deeper and broader understanding of the subject (Bybee 2015) The phase does, however, also serve the purpose of preventing the new knowledge from being situated, which can be characterized as knowledge that is bound to certain contexts and therefore cannot be used in other connections (Frisdahl 2014).

Feedback

In the Danish 6F-model, the feedback-phase is, as mentioned, not an independent final summative phase that allows teachers to evaluate the student’s progress toward the learning outcomes.
It should, to a higher degree, be understood as a continuous formative activity that is evident throughout the course of an inquiry session. It serves many

purposes and can take on different forms from teacher-student, student-teacher, student-student-feedback, just to mention a few.
From a teacher's point of view, the feedback received via interactions with and signals from the students, can provide valuable information about the progress of the students. This information is important and can allow the teacher to adjust the activities in order to promote student learning. Conversely, the teacher-student feedback is meant to guide the students, push them in the right direction and motivate them to learn even more (Frisdahl 2014; Yin, Shavelsen et al. 2008).

Learning as cycles

The 6F-learning cycle is thus basically a model that is meant to structure teaching by separating it into sequential phases. It is cyclic in nature, as the final phase of the teaching can lead to the initiation of a new cycle (Tanner 2010).

Its cyclic nature can however also be understood in another perspective that implies a number of cognitive benefits that I will now discuss. First, inquiry-based teaching, in general, often requires the students to repeat the learning process a number of times, when they find that their initial hypotheses should be altered, as their attempt to test it proves unsuccessful. Starting over multiple times will, each, time provide the students with additional knowledge about the specific hypothesis or subject at hand, which will then ultimately increase their conceptual understanding (Frisdahl 2014).

Inquiry-based teaching can however also be understood as a learning cycle that spans over a longer period of time. This perspective sheds light on how IBSE can help students to get familiar with the methods of a given science subject.
The first couple of times they conduct experiments, students are thus likely to experience insecurity and concerns related to social factors, such as group dynamics and methodical factors such as, how to properly design an experiment, how to minimize uncertainties in experiments or how to present their data in a manageable way (Frisdahl 2014). But with every inquiry-course, the students gain experiences and knowledge that, eventually, makes it easier for them to participate in the next inquiry-based lesson, as their contextual understanding is slowly being developed.

As a result, the students (and the teacher) will presumably experience inquiry-based teaching as challenging and time consuming when it is first implemented, as experiments fail, and the uncertainties seems inconceivable (Ibid). But in the long run, the students gain scientific literacy, process skills and conceptual learning, as they get used to the teaching method (Harlen 2004).

3. Research Background

This study has, up until this point, predominantly investigated the nature and backgrounds of inquiry-based teaching. I have, in the previous sections, briefly stated that IBSE enhances the scientific literacy and contextual knowledge of students, and that it additionally has a motivating effect, which promotes the students desire to learn. In this section, I seek to support these statements, by conducting a short review of the research concerning, how inquiry-based teaching leads to effective learning. After this, I present the opposing perspective in a short section that summarizes the criticism that inquiry-based teaching has attracted as well as the challenges that teachers experience when implementing it. And finally, to put IBSE into the context of this study, I conclude the chapter by reviewing the literature concerning teacher training and how newly educated teachers' implement inquiry-based teaching in practice.

Why use Inquiry-based Teaching?

Overall, several studies have found that inquiry-based teaching has various advantages and generally creates positive results (Minner, Levy et al. 2010; Furtak, Seidel et al. 2012; Kruse 2013). As an example, the most comprehensive meta-study on the subject, conducted by Minner et al. (2010), among other things, concluded that the conceptual learning of students, to a higher degree is promoted, if the students are actively brought to work, in constructing and applying concepts through the formulation of questions and systematic surveys, where they draw conclusions based on the evidence they themselves have found (Minner, Levy et al. 2010, Nielsen 2017). Furthermore Minner et al. conclude that students who participate in inquiry-based teaching, potentially can acquire a deeper scientific understanding than just the purely conceptual, as they found that these students, among other, were more committed to thinking independently and in general were better at using scientific methods (Ibid).

This argument is supported by Furtak et al. (2012), who compared effect sizes on 37 studies of inquiry-based teaching, and concluded that the teaching method has a positive effect on student learning. Kruse (2013) who cites several meta-studies backs this, and among other things, further argue that inquiry-based teaching has potential to promote students' desire to learn and increase their interest in science, because of its motivating effect (Kruse 2013). This argument is further supported by, among other Bentsen et al. (2009) and Wistoft & Stougaard, (2012), who found that a larger part of their observed students were motivated when they worked independently and created their own knowledge, compared to if they received teaching based on books.

Furthermore, Marshal & Alston (2014) compared the learning outcomes of inquiry-based teaching for various groups of students, and found that IBSE has a positive impact on the academic inequality that often occurs in a classroom, as

the academic differences between the students were leveled out in inquiry-based units. This included, among men, women and students with different cultural backgrounds (Marshall and Alston 2014).
Finally, Anderson (2002), concludes that inquiry-based teaching, in general, produces positive results, however, he also points out that this not happens automatically, as there are considerable variation in how IBSE is implemented in practice.

Criticism and Challenges of IBSE

While many researchers back IBSE as an effective way of teaching, there are also some who raises important points of criticism towards it.
The overall idea of IBSE, that students, who haven't been presented with any institutionalized knowledge, follow and imitate methods and practices similar to those of professional scientists, in order to acquire in depth scientific knowledge has thus, on several occasions, been criticized.

An often-used argument against IBSE is, thus that the teaching method lacks certain functions of authentic scientific challenges. As an example Wecker et al. (2013) points to the fact that it, in many ways, is an important prerequisite, in the professional academic world, that scientists are in possession of in depth scientific knowledge, before they commence their exploration, which is not reflected in IBSE.

In relation to this, an often-cited article by Kirschner et al. (2006), argues that students can not comprehend and explain scientific phenomena without the support of a teacher, as their abilities to do so, simply are insufficient.
This is further problematized by Sørensen and Thomsen (2011), who suggest that theoretical ideas will not emerge in the minds of students simply by doing practical tasks, as a result, they question IBSE, as they view this as an underlying assumption of the model.

In summary, there is an ongoing debate in the research community about if IBSE can be considered an advantageous way of teaching. Overall most arguments are in favor of the teaching model and usually refer to its positive results, and effectiveness in creating scientifically literate and motivated students, while arguments against, claims that students lack the ability to connect the experiences they make, while doing practical work, with theoretical knowledge.

Impediments to the Implementation of IBSE

Although the general message from research is that inquiry-based teaching produces positive results, it could seem that teachers are still not fully convinced that IBSE is an advantageous way of teaching, as research show that traditional 'teacher-centered' and 'textbook-based' education is still the most widely used way of teaching (Riga et al 2017).

In relation to this, Engeln et al. (2013) conducted a study, on the degree of implementation of inquiry-based teaching in twelve European countries, and concluded that the teaching method, still, does not have any notable presence in the classrooms of the studied countries.
There are several reasons, mentioned in the literature that explains why teachers chose not to implement IBSE in their teaching practice.
Persson (2017) summarized the most frequently mentioned, which can be seen in Table 3.

Table 3: The central reasons why teachers don't implement IBSE in their teaching. From Persson 2017. p. 34

The central impediments to the implementation of IBSE
x Confusion about what inquiry-based teaching entails (Colburn 2000, Harlen 2004).
x Insufficient competencies for inquiry-based teaching among teachers (Colburn 2000, Capps and Crawford 2013).
x The fixed nature of experienced teachers' beliefs about teaching (Luft, Whitworth et al. , Colburn 2000, Luft 2001, Engeln, Euler et al. 2013).
x The fact, or perception that inquiry-based teaching is difficult to manage (Colburn 2000, Akerson and Hanuscin 2007).
x Teachers are reluctant to relinquish control(Harlen 2004, Engeln, Euler et al. 2013)
x The fact, or perception that inquiry-based teaching takes longer time in planning and execution than other teaching methods such as direct instruction (Østergaard, Sillasen et al. 2010, Kruse 2013, Nielsen, Murning et al. 2017).
x A real or perceived lack of equipment and suitable teaching environments and other economic factors (Christensen & Greve 2016; Riga et al. 2017).
x Unaccommodating school policies and a lack of support from the school leadership (Harlen 2004)
x The growing focus on achievement rather than learning in education today (Bohm et al. 2017; Harlen 2007; Nordenbo & Allerup et. al 2009)

The importance of Teacher Beliefs and Experience

In addition to the impediments mentioned above, the beliefs held by teachers also play an important role in the implementation of inquiry-based teaching. Overall, teachers hold beliefs on a variety of matters, but research has found that beliefs directly related to the educational processes are the most salient to a teacher's classroom activities (Pajares 1992). This is among other, supported by Roehrig and Luft (2004) who, in their research report, categorize teachers beliefs about the educational process into; "beliefs about teaching, beliefs about students, beliefs about confidence to achieve a task, and beliefs about subject matter", and argue that "the teachers beliefs about teaching, have a direct and substantial impact on teachers' classroom practices, which to a high degree, is expressed in the implementation of IBSE" (Roehrig and Luft 2004 p. 3).

Teachers' beliefs, about educational processes, are often influenced by what kind of teaching they, themselves, have experienced as students, as a result, many teachers find it difficult to change their approach to teaching, as they have experienced science instruction as students that, in many ways, differ from IBSE (Loucks-Horsley, Stiles et al. 2009). These experiences served as templates for their own teaching, as teachers tend to teach as they were taught (Akerson and Hanuscin 2007). Logically a more widespread use of IBSE would eventually break the cycle of 'teacher centered' and 'textbook based' education, and further promote IBSE.

Professional Development

The previous sections have indicated that, even though inquiry-based teaching is generally being supported by research, science teachers often chose not to implement it into their teaching practice. There is, therefore, a permanent need to educate teachers to become comfortable with the teaching method, which often creates a new and complex classroom situation for both the students and for the teacher (Colburn 2000).
As the nature of inquiry-based teaching requires that teacher changes his/her role from being in control of the way students work, to scaffolding, guiding and supporting the students without interfering, the teacher must, thus, possess certain attitudes and skills in order to be able to facilitate successful inquiry-based teaching (Harris and Rooks 2010). First of all, the teacher must believe in the value of students having some element of control over what they will do, or how they will behave, but in addition the teacher also, among other, needs in depth knowledge of the subject that the students are investigating and some understanding of how students learn (in order to be able to provide effective feedback) (Colburn 2000).

The implementation of IBSE into the teaching practices of in service teachers is normally facilitated in various professional development (PD) initiatives, which is defined by Guskey (2002 p 381) as “systematic efforts to bring about change in the attitudes, beliefs and classroom practices of teachers, with the ultimate goal of improving student learning”.

However, in their article, Porter & Brophy (1988) argue that the reformation of the practices of science teachers are often impeded by a number of general problems. As an example, teachers are generally satisfied with the way they teach and as a result, “they do not view the benefits of changing their practice, as worth the investment of time and effort” (Porter and Brophy 1988 p. 82). In the case of IBSE this investment is significant, as teachers, in addition to lacking the pedagogical content knowledge about the method, doesn’t have sufficient knowledge about scientific procedures and the nature of science (Persson 2017; Capps and Crawford 2013).

In order to better facilitate teacher change, the designers of PT initiatives can, nevertheless, draw on an extensive body of litterature on how effective change occurs in educational settings (Akerson and Hanuscin 2007). It has among other been found that PD-programs of longer duration are most effective (Harlen 2004, Kazempour 2009, Capps and Crawford 2013), that if teachers get to follow-up and maintain their new skill or idea, they are more likely to use it in practice (Akerson and Hanuscin 2007) and, finally, that the teachers, in order to successfully implement changes in their teaching practice, need support from their school and leadership (Harlen 2004, Nielsen and Nielsen 2017).

Newly Educated, and Pre-service Teachers use of IBSE

Although teachers can benefit from professional development at any point in their career, various studies indicate that, teachers’ ideas about teaching and their own roles as educators, evolve during teacher training programs and the first couple of years of professional teaching (Roehrig and Luft 2004, Sadler and Klosterman 2009).

Therefore, pre-service teacher education programs that integrate practical inquiry exercises and pedagogical content knowledge about IBSE can be of significant value for the implementation of inquiry-based teaching.

Various studies have examined the ability of pre-service teachers to engage in inquiry-based teaching, in order to determine the feasibility of pre-service science teachers implementing IBSE.

As an example, Crawford (1999) conducted an in depth case-study of the practice of one pre-service teacher, over the course of a year, with the purpose of determining if pre-service teachers can manage the implementation of IBSE. Based on her observations, she concluded that this was possible, but that it would have been more manageable for the teacher, had she been better educated. Therefore Crawford suggests that:

- "In order to provide pre-service teachers with practice in the inquiry-process, pre-service teacher programs should engage pre-service teachers in authentic inquiry activities.
- It can be beneficial to place pre-service teachers in field experiences that model IBSE as that exposure may be an equally important element to developing teachers who teach inquiry in the science classroom.
- Pre-service teachers should have scaffolded practice with planning scientific inquiry units, and should be given opportunities to reflect on their own teaching "(Crawford 1999 qtd. In Sadler & Klosterman 2009).

In relation to this, Roehrig and Luft (2004) conducted a case-study, built on classroom-observations and interviews, with 14 beginning secondary science teachers that lasted for one-year, in order to understand factors that impacted their inquiry-based instruction. In general, Roehrig and Luft found that the teaching practice of the contributing teachers reflected their own life-experience, and that their beliefs about the abilities of their students and their prior teacher training in IBSE influenced their success with and challenges to inquiry-based teaching. They concluded that four features are needed from teachers if they are to implement IBSE successfully:

- "Contemporary views of nature and science
- Student centred beliefs
- Content knowledge
- Appropriate instructional context "(Roehrig and Luft p. 19)

Similarly, Sadler and Klosterman (2009) conducted a case-study that lasted for a period of two years, and involved fourteen beginning science-teachers, with the intention of documenting the development from pre-service science teacher, to the first years of full-time teaching.

They, among other things, found that the newly educated science teachers, who participated in their study, found it challenging to deal with, especially, the complexity of modern school policies and classroom management, which influenced the implementation of IBSE negatively (Sadler and Klosterman 2009 p. 43). As a result they concluded their study by suggesting that an increased focus on mentorship could support newly educated science teachers into becoming comfortable with teaching, which eventually would lead to increased student learning.

In summary

Several reasons explain why science teachers choose not to implement inquiry-based teaching into their teaching practice, as an example, the teaching method is seen as time consuming and difficult to control. To change this, various professional development initiatives are being completed. Research does however also suggest that, teachers' ideas about teaching and their own roles as educators evolve during teacher training programs and the first years of professional teaching, and, additionally, that teachers have a tendency to teach as they were taught.

As a result, pre-service teacher education that integrate practical inquiry exercises and pedagogical content knowledge about IBSE can be of significant value for the implementation of inquiry-based teaching

4. Research Questions

I have up until this point of my study found that IBSE is a teaching strategy that emphasizes the methods and nature of science at the same time as it leads to applicable conceptual understanding. Learning through inquiry can thus potentially provide a deeper understanding of a given topic and increase the scientific literacy and the learning outcomes for the individual student. Furthermore, it has been suggested that inquiry-based teaching can be an effective way to implement practical work, and to make students take responsibility of their experiments, which in general can have an engaging or motivating effect.

However, to this day, IBSE is still not much employed in the daily practice of Danish science teachers. Research has found that several factors limit its implementation, these, among other things, include that teachers tend to view IBSE as time consuming and difficult to control, and that far from every teacher is properly educated in how to apply the teaching method.

Newly educated science teachers from The University of Copenhagen has, however, been thoroughly introduced to IBSE, at the mandatory course[4] Advanced Methods of Teaching Science[5], which has been offered by The Department of Science Education since 2008, why they, in theory, should have a basic understanding of the teaching method, and be able to implement it into their teaching.

To test this, I have conducted interviews with six science teachers, in order to learn about their experiences with and perceptions and understandings of inquiry-based teaching. In addition, I have observed three of the teachers teach an inquiry-based module, to understand how IBSE is implemented in practice.

My work has been based on the following questions:

[4] The course is mandatory for students who seeks a career in teaching

[5] A formal description of 'The Advanced Methods of Teaching Science' course is attached as appendix B

Research questions:

1. **How do newly educated science teachers, from the University of Copenhagen, understand and perceive inquiry-based teaching?**

2. **How does the implementation of IBSE take place in practice?**
    - **To what degree does the teachers use the 6F learning cycle in their teaching?**
    - **To what extent are newly educated science teachers able to implement IBSE into their teaching?**

3. **What benefits and difficulties do teachers experience when using IBSE.**

- **Does IBSE have a motivating effect on students?**

5. Methodology

In the following chapter, the research-approach and applied methods of the study are described. As in the previous chapter, it is divided into subsections that hold together, explain the many methodological considerations I have made.

In the first section the thoughts behind the research design is explained. This is followed by a section, in which I briefly describe the limitations of the study. The participants involved in the project and the recruitment process is then explained in the third and fourth sections. Finally the fifth and sixth sections explain the two types of data collection that I have used.

Research Design

In order to investigate science teachers' perceptions of, and experiences with the implementation of inquiry-based teaching, this study has predominantly been guided by a qualitative research design, primarily based on semi-structured interviews with teachers, but also on observations of their teaching, in practice.

This approach was chosen in favour of a more quantitative method, as my area of interest is to investigate teachers' believes and perspectives, which are concepts that are difficult to quantify, but well fitted to a qualitative approach.
This is encapsulated by Berg (2007), who describes "that qualitative exploration provides an opportunity for researchers to access 'unquantifiable' facts about the actual people they observe and talk to, and in extension to this, allow researchers to share in the understandings and perceptions of others and to explore how people structure and give meaning to their daily lives" (Berg 2007 p. 7).

It is in this context important for me to add that I do not view the qualitative and quantitative methods as mutually exclusive, but rather as methods that hold different analytical advantages, suited to extract different types of data.

I, thus, originally considered adding a more quantitative angle to my study, as I felt that this could benefit my results in several ways, as it could provide answers to more quantifiable questions and offer a greater degree of validity to my findings, especially in relation to my research question; if IBSE has a motivating effect on students. This thought was, however, dismissed on an early state of the project, as I soon learned that the number of people who met the requirements to participate in the study, was smaller than I had initially considered, which made it difficult for me to deploy a significant quantitative approach.

Instead, I have deployed a thematic analysis to my interviews that is meant to target the views, understandings and perceptions of the participants and provide an in-depth understanding of teachers' thoughts and experiences with IBSE.

Furthermore, I have conducted a descriptive analysis of my classroom observations that focuses on how teachers implement IBSE in practise, and as a result emphasize structural parameters such as the use of 6F-phases, feedback and motivation. The analytical approaches are further discussed in chapter 6.

Limitations

As I myself have been a student at the Advanced Methods of Teaching Science-course (AMTSC), I have extensive knowledge about the curriculum and the activities of the course; in other words, I know what the participants in this study are supposed to know about IBSE. I am, conversely, limited by the facts that my major subject is Geography, and that I have limited teaching experience. Classroom management, school policies and the individual subjects of the interviewed teachers are therefore not my specialty. As a result, I may have gotten some details wrong, when observing the three modules. As an example I am still, to this day, not entirely sure about how to measure the point of equivalence, which was an important part of Charlie's lesson. This is, however, not seen as problematic, as it was more important for me to examine the structure of the lesson, than its academic contents.

Recruitment Process and Participants

In order to investigate science-educators perceptions of and experiences with inquiry-based teaching, an essential demand of this study, has been that the participants must be familiar to IBSE. To meet this, the recruitment-process was conducted on the background of a list with the names of every student who has participated in the Advanced Methods of Teaching Science-course (AMTSC), from the year 2011-2012 to 2017-2018, a list, which was made in collaboration with my supervisors.

It turned out that, in all, 79 people had participated in the course.
Via personal contacts, social media, Linkedin and an extensive amount of research I was able to establish that at least 23 out of the 79 participants, actively works as educators in primary schools, upper secondary schools, HF[6], Folk high schools [7] and in museums.

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[6] HF is a two year highschool certification track.
[7] A folk high school is a non-formal residential school offering learning opportunities in almost any subject. Most students are between 18 and 24 years old and the length of a typical stay is 4 months. It is a boarding school, so you sleep, eat, study and spend your spare time at the school. There are no academic requirements for admittance, and there are no exams - but you will get a diploma as a proof of your attendance (www.danishfolkhighschools.com).

I attempted to make contact with all 23 by sending a standardized 'call for participants' (Appendix C), primarily via email[8]. In the email I informed the teachers that my project was about their experiences of and perceptions of IBSE, but that substantial knowledge about the teaching method was not a requirement to participate in the study. Furthermore, I outlined the requirement for participation: Participating in an interview lasting approximately 30 minutes and if possible, letting me observe a lesson in which IBSE to some degree was used. Lastly I guaranteed full anonymity in the finished report[9].

I am aware that the information in the call for participants may have influenced which teachers responded to the call, as factors such as scepticism towards IBSE or fear of insufficient knowledge about the teaching method could keep some teachers from volunteering. Conversely, the respondents who did, in fact, chose to volunteer, could potentially have an extensive knowledge about the teaching method, which to some extent was confirmed by the fact that five of six participants had written their own theses at The Department of Natural Science.

In the end, out of the 23 people who where contacted, six teachers volunteered to participate in the study.
Table 4 gives a basic overview of the participating teachers who, with one exception, all teach in schools located in moderate proximity to Copenhagen.

Table 4: Participants of the study

Participants				
Teacher	**Age**	**Teaching experience**	**School**	**IBSE applicable Subjects**
John	27	1 year	Upper secondary	Biology
Mick	29	2 years	Primary school	Biology
Charlie	27	2 years	HF	Chemistry
Elisabeth	27	2 years	Upper secondary	Physics
Jeff	29	4 years	Upper secondary	Physics
Anne	40	6 years[10]	Upper secondary (e-course)	Chemistry

[8] In a few cases I did not manage to find the correct email, why contact instead was attempted via Linkedin or Facebook.

[9] To achieve this anonymity, I refer to the teachers by pseudonyms throughout this report.
[10] It can be discussed if a teacher with 6 years of professional experience can be classified as 'newly educated', but as Anne partook in the AMTS-course in 2016, I have chosen to do so.

Data Collection

As described in the previous section, I have combined interviews and classroom observations to gather data to help me answer my research questions.
In the following section I discuss the design and use of both of these methods

Time and Place

As the Interviews and especially the classroom observations were all to be done before the final exams and before a potential lockout and strike began in mid April, they were conducted between March 12 and April 13. Four of the six interviews took place at the schools of the teachers, but due to geographical reasons, one was conducted via Skype and one took place at a Library in Roskilde, which is the hometown of the teacher, who commutes to work.
The interviews lasted for approximately 30 minutes and were all recorded for further analysis, they were conducted in private, usually in a meeting room, but as mentioned, one was conducted from IND via Skype.

Interviews

"An interview can be classified as a research method that takes the form of a conversation, it differs from the everyday conversations by being more focused on questioning and listening. It is conducted by the researcher, who is focused on structure and purpose, as he has a clearly defined agenda, and as a result it is the researcher who controls the direction of the interview (Kvale & Brinkmann 2009). Similarly to IBSE, the degree of openness in an interview can vary, from completely open informal conversations, to carefully structured interviews, where everything is planned into detail (Ibid).
I have chosen to characterize my interviews as semi-structured as they fit into the following definition from Kvale and Brinkmann (2009):

"The semi-structured interview is an attempt to understand themes from the daily lives of the interviewee seen from the perspectives of the interviewed person (…) it approaches ordinary conversation, but has as a professional interview purpose and entails a certain approach and technique; it is semi-structured –which means that it is neither and open conversation, nor a closed questionnaire (Kvale & Brinkmann 2009; p 45)".

As my agenda was to gain insights about my informant's experiences and perceptions of IBSE, I mainly based my interview guide[11] on questions related to inquiry-based teaching I did however also include four questions that were meant to incite the informants and to get them to relax. These were more or less all related to the informants teaching practice in general.
The conversation during the interview did not follow my interview-guide to the

[11] The interview-guide is attached as Appendix D

letter, but instead revolved freely around the questions that I had prepared and various follow-up questions, which is common practice in semi-structured interviews (Kvale & Brinkmann 2009).

As I wanted my study to remain as objective as possible, it was a clearly defined focus point for me to complete my interviews without being biased.
Therefore, I tried to ignore the knowledge of IBSE that I had gained through my literature-review and my interviews with the other informants.
Instead I tried to stay open and curious to the information I received from the interviewed teachers, without "chasing hypothesis", which is an approach Kvale & Brinkmann (2009) refer to as conscious naivety.

Furthermore I focused on asking non-leading open-ended questions designed, so that the informant's answers were based on their own experiences and not on my predefined knowledge and interpretation.
Finally I conducted a pilot interview with one of my fellow thesis students at the Department of Science education, who has also been a student at the Advanced Methods of Teaching Science-course, and as a result could provide me with valuable feedback about my interview guide and my questions.
In the end the interviews provided me with valuable insights about science teachers perceptions and views of inquiry-based teaching.

Classroom Observations

Originally I indented to observe all of my informants in order to learn how they use IBSE I practise, but due to various circumstances[12] I only managed to witness Mick, Charlie and Elisabeth in action.
Even though the purpose of my observations originally was to gather data concerning the motivating effect of IBSE on students, I soon learned that my observations contained valuable information that, not only could help me validate what the informants told me in the interviews, but also had potential to show me, how teachers use IBSE in practise in their classrooms.
Table 4 is a short characterisation of my observations that are further discussed on the upcoming pages. For a more detailed overview of the observations, observation-protocols are attached as appendix E.

[12] I wasn't able to observe Johns lesson because of the geographic distance. Observation of Jeff's lesson was cancelled due to illness and finally observation of Anne's lesson was limited as she conducts e-courses.

Table 5: Overview of the observed classes

Teacher	Subject, level and programme	Number of students	Classroom	Lesson topic	Lesson Duration
Mick	Biology 7th grade, (private school)	24	Ordinary classroom	Farming and Exercise and Diet	90 minutes
Charlie	Chemistry HF	20	Chemistry lab	Filtration of acid & the point of equivalence	110 minutes
Elisabeth	Physics STX 1st year	22	Ordinary classroom	Light and wavelengths	90 minutes

Participant observation

I would largely characterise my observations as a form of participant observation, which is one of the best-known methods in social sciences (Bryman, 2012). "In this form of observation, the observer is present at a social setting in which he or she seeks to observe the behaviour of members of that setting" (Bryman, 2012 p. 273), in this case the students and the teacher.

An important aspect of observation-based research is that observers can vary in how much they participate in the setting that they are located, and in continuation of this, in how structured they choose their observations to be (Ibid). To classify my observations further, I refer to the ethnographers DeWalt and DeWalt (2011), who have defined five levels of observer involvement (Table 6).

In accordance to DeWalt and DeWalt, the level of my participation can be classified as moderate, as I was introduced to the students as a researcher in all of the three observed classes, but not actively participated in the teaching activities. I did however talk to several students in order to learn what they thought about doing experiments, which potentially could have influenced the students' behaviour, as a general disadvantage of participant observation is that a researcher's presence and interactions can affect the environment being investigated (Bryman 2012), in this case, the way the students (and the teacher) acted. When taking this into account, I could unintentionally have influenced the social setting that I had set out to document, from the very moment that I stepped into the classroom, even though I intended to make my observations as non-intrusive as possible. I must however ad to this, that none of the students or teachers, that I observed, seemed to be particularly affected by my presence.

Table 6: Levels of observer involvement Based on Dewalt and Dewalt, 2011 p. 25.

Levels of observer involvement
Nonparticipation: The observations are made from outside the social setting: e.g. by watching through a one-way mirror, by reading texts or following website chats. **Passive participation:** The researcher is on the spot, but does not interact with anyone, as he is purely acting as an observer or bystander. **Moderate participation:** The researcher is identified as an observer, but does not actively participate or only occasionally interacts with people in it. **Active participation:** The researcher actively participates in the activities of those being observed, as a means to learn the cultural rules for behaviour in the social setting. **Complete participation:** The researcher becomes an active member of the group being studied.

By being physically present in the classroom, I nevertheless managed to get a rich data source that documented IBSE in practice, which I would not have been able to uncover by solely conducting interviews.
While observing the classroom activities I took notes on an observation-protocol that I had made, based on the observation schedule-recommendations presented in Bryman (2012)[13].

This protocol was, primarily, meant to help me remember what went on in the classrooms, but it did also serve the purpose of documenting: the classroom activities, the level of student engagement, what phases of the 6F-model that was being taught and what forms of feedback that was used in the different phases.

My intention was to create a descriptive analysis of what went on in the observed classrooms; therefore I aimed to record the teaching, in as much detail as possible, and not in a particularly quantifiable way. Consequently I will not characterize my observations as exceptionally structured, but rather as a summary of the classroom activities, which in the end helped me answer two of my research questions:

[13] The protocol is attached as appendix E

- How does the implementation of IBSE take place in practice?
- Does IBSE have a motivating effect on students?

6. Analysis and Results

In order to derive as much as possible from my data, I have, as mentioned, chosen to use two different analytical approaches to dissect my findings.
My classroom observations have thus been the subject of a descriptive analysis, with the main purposes of learning; how teachers implement IBSE in practice, and if IBSE has a motivating effect, while the interviews, that I have conducted, have formed the basis for a thematic analysis that is meant to illustrate the interviewed teachers' perceptions and understandings of IBSE.

To create simplicity I have attempted to keep the two analyses somewhat separated in this chapter, why I start out with presenting the descriptive analysis and the results it provided me with, before I go on to present the thematic analysis and the results that went with it. I have nevertheless included information, from the interviews, about how the teachers plan their lessons, in my descriptive analysis, as I viewed this as key information about how teachers implement IBSE in practice

Descriptive analysis

As mentioned, I have used the data from my observation-protocols (Appendix E), as the basis for a descriptive analysis, In order to investigate how the participating teachers integrate IBSE into their classes.
I have chosen to use this analytical approach as its descriptive methodology allows me to present the observed classes in a nuanced way, and at the same time provides me with results that are directly comparable to each other (Bryman 2012), which is an advantage as I compare the three lessons when presenting my results.
In general the descriptive analysis holds several methodological and investigative possibilities, but in this study I have mainly chosen to focus on the following five parameters, as these, not only, as earlier described, can be characterized as important elements in inquiry-based teaching, but also because they encapsulate the overall aim of my study.
The five parameters are:

- The structure of the module
- The level of inquiry
- Student engagement
- Feedback

- x The 6F phases used by the teacher

To give a better overview of my findings and to present the observed modules as nuanced as possible, the analysis of each class has been divided into three parts. I thus start out by presenting the observed module in a short explanatory narrative that sets the scene, describes what went on in the module, and explains aspects of the teaching that would lose meaning if they were to be schematized, this could for instance be the profile of the visited school, or the teachers thoughts about the observed class.

The second part of the analysis is constituted by a Table that is meant to serve as the link between my observations and my analysis, in the Table I have thus summarized the classroom activities and divided the modules into the different phases of the 6F-model, whenever it was possible.
In addition, the tables include information about what kind of feedback I detected in the different phases, and the students' level of engagement, which is valued from 1-5, calculated from the percentage of students that were engaged in a given activity/phase[14].

In the third, and final, part of the analysis I elaborate my observations with emphasis on the abovementioned five parameters, which basically means that I analyze how the teaching was structured in accordance to the 6F-model and review the level of inquiry and the level of student engagement in the observed classes.

Finally after I have presented and analyzed each lesson, I compare them and present the results of my analysis.

Mick

The first informant that I observed was Mick, who works at a major suburban private primary school, where he teaches the subjects Biology and Mathematics. When I observed him on March 13. 2018, he taught Biology to a seventh grade which on the day consisted of 25 pupils at approximately 13 years of age.
The module that I observed functioned as the end of a larger unit concerning agriculture and food production, and as the beginning of a new unit about exercise, diet and the functions of the body.
Therefore, he told me, the first part of the module was largely devoted to an extension phase, where the students, in pairs, had to fill out a questionnaire with five questions about agriculture that the pupils individually had created as part

[14] An engagement level of 4 thus means that approximately 80 percent of the students worked concentrated in a given phase.

of their homework from the previous module, while the second part of the module was all about getting started with the new unit, with the theme; Exercise and the functions of the body. This was planned to last for the following five weeks. Consequently the majority of the second part of the module was devoted for, an experiment where the students, in groups, tested their heart rate after having done different forms of exercise, by using the app "Heart rate monitor".

The module was composed by several shorter activities that lasted from 5 to 30 minutes, in which the pupils worked in pairs, in groups and in plenum and in different ways that would allow them to be active, why they were not sitting on their chairs for more than five minutes at a time.

As an example, in the explorative phase, the pupils were divided into groups consisting of approximately three persons, and asked to perform five different forms of activities, while monitoring their heart rate. The pupils were not given any direct instructions besides a short introduction to how the app worked; as a result I witnessed some pretty creative ways to do exercise, the most common forms was however, to run in the schoolyard, to run on the stairs of the school, to do pushups, and to walk slowly back and forth in the school hallways.

The pupils did this for approximately 35 minutes before they were gathered in the classroom, and handed their homework, before being dismissed. The purpose of the homework was that each pupil had to do five different forms of exercise, while monitoring his, or her, heart rate, at home. In the following module Mick would then ask the students to explain which forms of exercise that would cause the highest heart rate, and discuss what this in general meant.

Table 7: Observation of Micks teaching. S-S = student to student feedback, T-S = teacher to student feedback, S-T = student to teacher

Observation of Mick's lesson					
Interval	**Phase**	**Student-activity**	**Teacher-activity**	**Feedback**	**Engagement level and Reason**
0-10	Extend A	The students work in pairs and solve each other's questionnaires about agriculture, which was the subject of the previous module.	Presents the activity and makes sure that everyone has a partner	S-S	**4**: Not everyone has done their homework
10-15	Extend B	Validation: The pupil who has made the test, corrects it.	The teacher circulates in the classroom and asks questions related to the tests.	S-S	**4**: not everyone has done their homework
15-20	Extend C	The pupils discuss their tests and looks for good and bad questions.	The teacher makes sure that all the pupils are active, also the ones who haven't made their homework	S-S	**5**: At this point all the students are engaged in the discussion
20-35	Extend D	Classroom discussion, what is a good question?	The teacher facilitates the discussion and asks explanatory questions	S-S, T-S	**4**: Some of the students have lost their concentration, maybe as a result of the imminent break
35-40	Break	-	-	-	-
40-50	Elicit	In pairs and then in plenum, the students attempt to categorize how much they move in a week	The teacher asks individual students to estimate how much, and in what way they exercise in a week, which is a difficult question to answer for many of the students. He writes the estimations on the blackboard	S-T	**5**: The students are highly motivated as they can relate to the subject
50-85	Explore	In groups the students make 5 different exercises by own choice, and measure how their heart rate is affected. Some of the groups do this in the schoolyard, in the stairway and in a vacant adjacent room	The teacher makes sure that everyone has understood the assignment, and circulates from group to group, asking questions.	S-S, T-S	**5**: At this point of the lesson all the students are active, during exercise and measuring their heartbeat.
85-90	-		The teacher presents the homework		

The Structure of Micks Teaching

Due to the fact that he had divided the module into smaller parts, where the pupils were allowed to work in different constellations, Mick's teaching appeared very dynamic. In all, I detected three phases of the 6F model: Extend, Elicit and Explore, which interestingly, were not implemented in the 'conventional' order, as presented in Chapter 2, as Mick started the class with an extension-phase and ended it with an exploration-phase.

Micks reverse use of the 6F-model can be explained by the fact that the module that I observed, functioned as the end of one unit and the beginning of another. Even though I thus observed two different 6F-cycles I did not observe a 'pure' explanation phase, where the students had to present their findings, nor did I observe an engaging phase. It can nevertheless be discussed if the couple of minutes Mick spent explaining how the app worked, in it self actually can be considered engaging to the pupils, as they seemed very eager to get started and try it out.

As seen in Table 7, I detected several forms of feedback. The first part of the lesson, where the students worked with each other's questionnaires was thus characterized by student-student-feedback, while teacher-student and student-teacher feedback was present throughout the rest of the teaching.
Figure 3 is a representation of the amount of time that was approximately spent on each phase.[15]

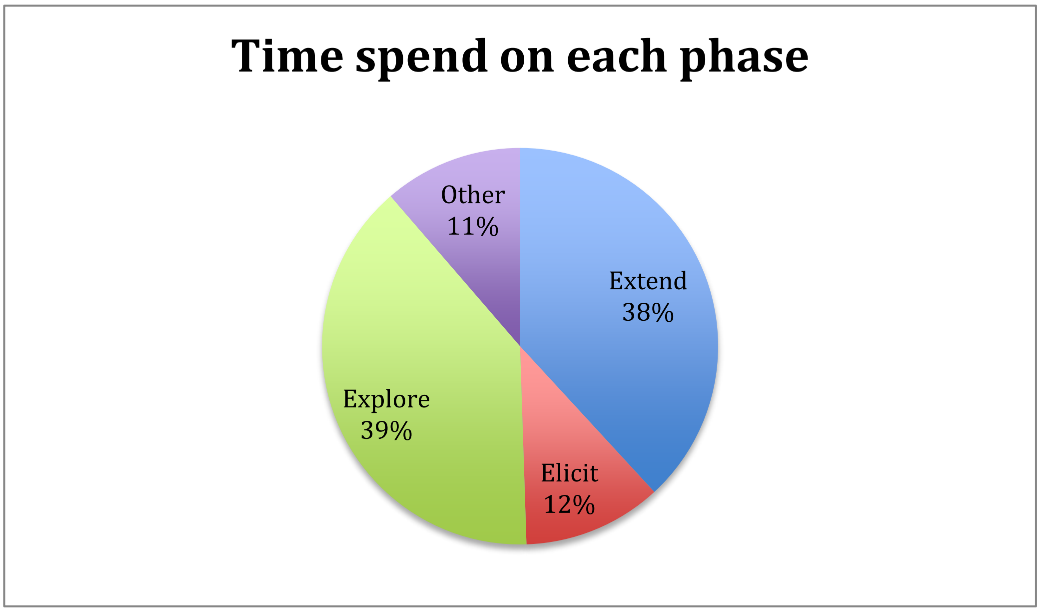

Figure 3: Time spend by Mick on each phase of the 6F model

[15] The amount of time spend on each phase is noted as percentage in order to better compare the different lessons, which were not equally long.

Level of inquiry

The level of inquiry can be classified as structured as Mick explained to the pupils what they had to investigate and clarified how the app they should use, functioned. The main responsibility of the pupils was thus to come up with different 'variables' (ways to exercise) to examine.

As mentioned, the academic level of a class is an important factor for what level of inquiry a teacher can introduce. This clearly also played a part in Micks module. He thus repeatedly had to answer simple methodological questions from the different groups. As an example, several groups experienced uncertainties about whether to measure the pulse before or after the exercise. Additionally I witnessed some pupils who experienced problems with getting the app to work.

Student engagement

Even though the module that I observed was taking place from 12-14 in the afternoon, the pupils' engagement was generally at a high level.
I thus, at no point of the teaching, detected more than five pupils being inactive at the same time. This could have something to do with the way Mick had structured the lesson, which entailed that the students continuously had to work in different ways.
It could however also be related to the nature of the experiment, which required that the pupils made inquiry by exercising in different ways.
In the final exploratory phase it thus seemed as if the pupils were not only engaged in their work, they seemed to have a great time.
The pupils' level of engagement during the three phases is illustrated in Figure 4.

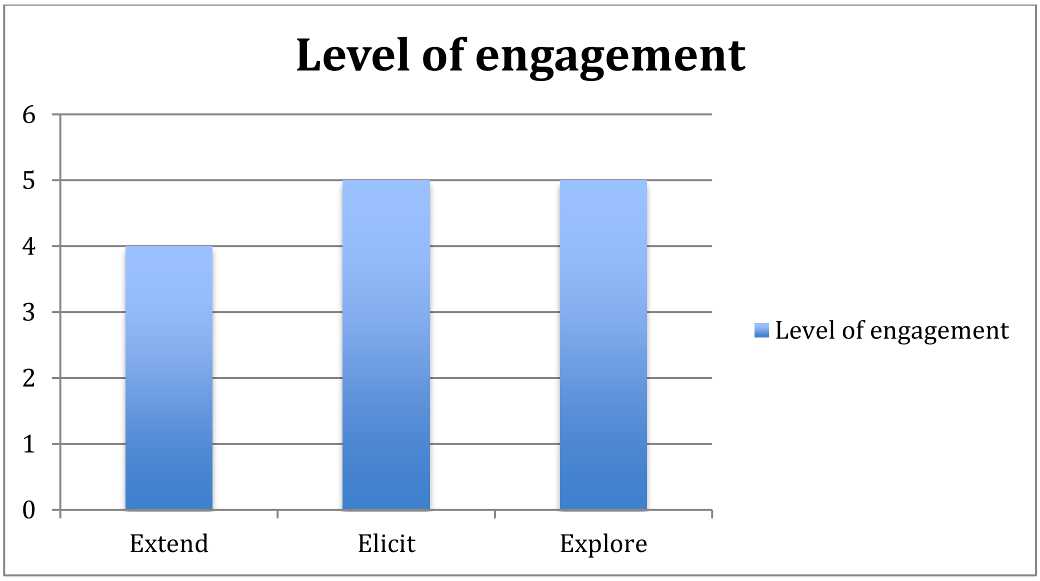

Figure 4: Mick's pupils level of engagement in the different phases of the module

In summary I witnessed a module that was divided by two different units and 6F-cycles, where Mick applied the phases Extend, Elicit and Explore. The entire module was to a high degree student centred and the pupils seemed to be very engaged throughout the teaching and especially in the exploratory phase. The level of inquiry can be characterized as structured as it was the teacher who provided the procedures and materials, but the students who did the investigation.

Charlie

The second informant that I observed was Charlie, who works at a large HF in northern Copenhagen, where he teaches chemistry at C and B levels.
As mentioned, HF can be characterized as a two-year high school certification track that gives access to higher education.
In general many different types of people choose HF in favor of STX but there is a clear pattern among a large proportion of the students.
A survey conducted by the Danish Evaluation Institute (EVA) in 2015, thus concluded that HF students more often have poor grades from primary school, are tired of going to school and, to a higher degree, previously have dropped out of several youth programs. In fact 48 percent of the students at HF have interrupted one or more programs of youth education , and 12 percent of the students have taken a break after the 10th grade before they signed up for HF (EVA, 2015). As a result, the average age in the HF classrooms is higher than in upper secondary schools.

When I observed Charlie on March 20, 2018 he taught chemistry to a first year HF class, who had chemistry on C-level. The observed class consisted of 22 students who were approximately 20 years of age.
Before the lesson, Charlie, interestingly, told me that it is the schools policy that the curricula of the different first year classes are synchronized so that all the classes in essence are taught the same things, which he as a young teacher thought was an advantage, as he could then focus more of his energy on the teaching instead of on the planning. However, as a result, Charlie had not planned the experiment the students were to do, in the module that I observed.
Additionally he also told me that the experiment the students did, was by far the most difficult in the school year.
As a result Charlie had handed out manuals that, in his own words, unfortunately changed the experiment from being pure inquiry to a cookbook-exercise.
He did, nevertheless, apply four of the phases from the 6F model in the module, these can be seen in Table 8.

The observed module overall consisted of five different activities that to some extent made the teaching seem dynamic. In the first 15 minutes the students thus played a memorizing game, in pairs, where they had to use their conceptual knowledge to remember different materials from the chemistry lab. This was followed by 10 minutes where the students could ask questions regarding the upcoming examination and the implications of the possible lockout. After this, the class talked about the point of equivalence, which led to the experiment, in which the students had to find the amount of ethanic acid in household vinegar using phenolphthalein. Finally the students, who completed their experiments, could spend the remaining part of the lesson, working on a report about acids and bases, which also functioned as the homework of the day.

Table 8: Observation of Charlies teaching S-S = student to student feedback, T-S = teacher to student feedback, S-T = student to teacher

Observation of Charlie's lesson					
Interval (Minutes)	**Phase**	**Student-activity**	**Teacher-activity**	**Feedback**	**Engagement level and Reason**
0-15	Engage	The students play the game in pairs. In the game the students must remember and answer different questions about acids and bases	Presents the subject of the day and hands out a small game.	S-S	**3**: The students are engaged by the game, but several of the students spend the time talking about other stuff
15-25	-	Asks questions about the upcoming examination and the consequences of the possible lockout	Answers the students questions	T-S	**4**: Most of the students are interested
25-30	Elicit	In pairs the students get 1 minute to talk about what the point of equivalence is. The discussion is continued in plenum	The teacher facilitates the discussion and answer questions	S-S, S-T	**3**: Most of the students are motivated, but some are not paying attention
30-65	Explore	In groups of 3-4 persons, the students perform an experiment, that is guided by a manual	The teacher circulates in the classroom and helps the students when they need it.	S-S, T-S, S-T	**4**: in the beginning the students level of engagement is high, but as they finish in different pace, the level of engagement drops for the students who complete the experiment
65-75	Break	-	-	-	-
75-110	Explain	The students write a scientific journal in which they answer the questions listed on the manual.	The teacher still circulates and answers questions	S-S, T-S, S-T	**3**: At this point of the lesson many of the students seem to have lost their interest as they talk about other things

The Structure of Charlie's Teaching

The observed module was in principal made up of four different 6F-phases: The first 15 minutes, where the students played a memorizing game, was thus meant to function as an engage-phase, as the students interest, at least to some degree, was captured by playing the game.
After 10 minutes of practical questions, I then observed a short eliciting phase, where the students discussed the point of equivalence. This led up to the experiment, which was the central part of the module, and finally the students had time to explain their findings in a written assignment, in the remaining part of the lesson.

It should be mentioned that the nature of the experiment resulted in some students completing the experiment in their first attempt, while others had to use several attempts. As a result the exploratory phase took 35 minutes for the majority of the students and 70 minutes for the groups who could not reach the desired results. This obviously have had some implications for my own calculations of the percentage of time spend on the different phases; I have, however assessed that the exploration phase approximately lasted for 35 minutes as this was the case for the majority of the students. Consequently the explanatory phase is also set to have lasted for 35 minutes.

I wouldn't characterize the module as exceptionally dynamic as the length of the exploration phase, where the students followed a manual, meant that there were not many changes in student activities. However, I do not think that the students felt the same way, as they were busy doing research, while I, as an observer, may have experienced the module differently.
The first part of the module where the students played a memorizing game was characterized by student-student-feedback, while student-teacher and teacher-student feedback to a high degree was present throughout the exploration-phase as Charlie would circulate in the class and help the students whenever it was needed, in Figure 5 the percentage of the module that was spend on each phase is calculated.

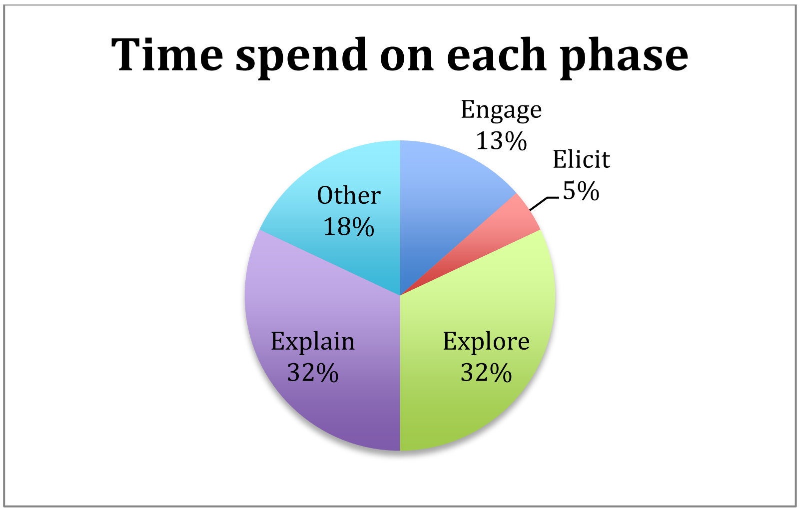

Figure 5. Time spend by Charlie on each phase of the 6F model

Level of inquiry

As Charlie himself pointed out before the lesson started, it is hard to characterize the teaching as inquiry-based, as the students followed manuals to complete the experiment. He further told me that it generally was a challenge for him to let his C-level students, structure their own experiments and work without any guidelines, as their basic conceptual knowledge and scientific literacy was often to low to do so. When reaching the B level, the students' competences were often developed to a degree, where he could change the level of inquiry and let the students put together their own experiments.

As a result I cannot classify the teaching as Inquiry-based, but rather as a cookbook exercise, even though Charlie, in theory, managed to include four phases that fit with the 6F-model.

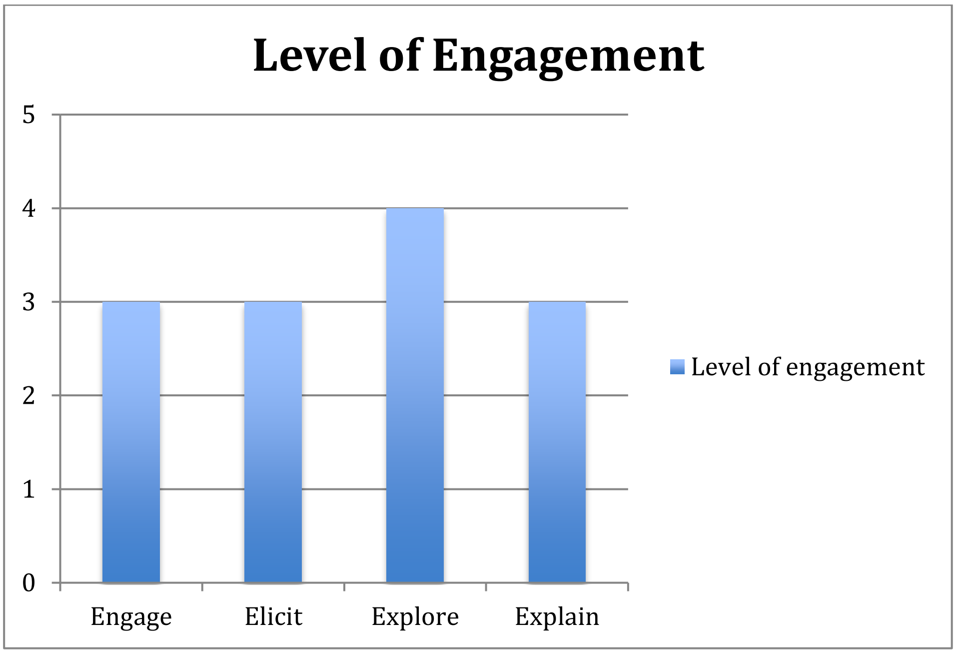

Figure 6: Charlies students' level of engagement in the different phases of the module

Student engagement

Throughout the module, the students were doing most of the classroom activities; I thus did not observe Charlie talk for more than 5 minutes at the time, why the teaching generally appeared to be very student centred.
Despite of this, the students did not seem to be very engaged in the first half of the module, as a group of the students did not seem to be paying attention. This did, however, change when the exploration-phase was started. At this stage of the teaching, it seemed that almost all students were busy investigating and experimenting.
The experiment was, however composed in such a way that some groups were finished earlier than others, with the result that the students that finished the experiment, lost interest and motivation.
In the last part of the lesson, which was reserved for the students to write journals, the level of engagement was even further reduced. This was perhaps due to the fact that it was Friday afternoon and the students, as a result, mentally were heading for the weekend, the students were, however, additionally distracted by three persons from the schools student cap-committee, who entered the classroom as they wanted to recruit new members.

In summary, Charlie's module was structured around an experiment about acids and bases. Due to the difficulty of the experiment the students were handed manuals, why the teaching cannot be characterized as inquiry-based.
The module consisted of four of the 6F-models phases and even though the students, in the beginning of the lesson, did not appear overly engaged, their commitment increased during the exploratory phase, before it dropped in the end of the module.

Elisabeth

The third teacher that I observed was Elisabeth who teaches physics and math at a large gymnasium in Roskilde. When I observed her on April 6, 2018, she was teaching physics to a first year-class with around 20 students who, in her opinion, generally were well functioning and skilful.
The module that I observed was not based on one single experiment but rather on many short phases, where the longest lasted for approximately 30 minutes and was reserved for the students to finish a report about the wavelength of light, which was also the overall subject of the unit, which was scheduled to last for five modules. In continuation of this, Elisabeth later told me that it was school policy that written assignments were made during the classes, why she had to earmark time for this in many of her modules.

Throughout the teaching, the students worked in several different ways and in varying group constellations and were continually being engaged by Elisabeth

who would use different materials, which elaborated her main points and caught the attention of her students.
As an example she showed two short video clips that served different purposes. One was thus meant to elaborate an important point about the electromagnetic spectrum, while the other was meant to engage the students and teach them something about UV-radiation.

In all, I detected six different stages in the module. The first one lasted for 30 minutes and was, as mentioned reserved for the students to work on a report about the wavelength of light. After this, Elisabeth and the class spend 10 minutes on drawing up an overview of the electromagnetic spectrum on the blackboard and watched a short film about the subject, this was followed by two short phases where the students first talked, in pairs, about the advantages and disadvantages of UV-radiation and then watched another short film, which illustrated how sunscreen works.
After this, Elisabeth split the class into groups and handed out three infrared cameras. Importantly, she did not give the students any exact information about what to do with the cameras, instead she only told the class to take photos of different things and figure out how the cameras worked. The students then left the classroom to take photographs of different objects.
After approximately 20 minutes, the students returned to the classroom with the cameras, Elisabeth was then quick to upload some of the photos to her computer, so that she could present them on the smartboard and ask the students to explain different aspects of the photographs that they had taken.

Table 9: The structure of Elisabeth's teaching S-S = student to student feedback, T-S = teacher to student feedback, S-T = student to teacher

Observation of Elisabeth's lesson					
Interval (Minutes)	**Phase**	**Student-activity**	**Teacher-activity and feedback**	**Feedback**	**Engagement level and Reason**
0-30	Explain A	In groups the students work on a report about their experiments from the previous lesson about the wavelength of light	Circulate and give feedback wherever it is needed	S-S, T-S, S-T	**4**: It takes time for some of the students to get started
30-35	Break	-	-	-	-
35-45	Extend	The class makes an overview of the electromagnetic spectrum and watches a small movie about the subject	Guides the students, draws the spectrum and puts on the movie	S-T	**5**: At this point all of the students were motivated, especially during the movie
45-50	Elicit	In pairs the students talk about UV-radiation	The teacher shifts the attention to UV-radiation and asks the students to talk about positive and negative effects of the suns radiation.	S-S	**4**: Some of the students talk about other things
50-55	Engage	The students watch a small film about how sunscreen works	Puts on the video and asks the students about their thoughts at the end	S-T	**5**: The film clearly engage the students
55-80	Explore	In groups the students use the IR cameras to take photos of different objects. They do this outside of the classroom	The teacher has brought 3 IR cameras that the students are allowed to try out.	S-S	**5**: The students are highly engaged by the cameras
80-90	Explain B	The students explain different aspects of their photos	The teacher shows some of the photos on the smartboard and asks the students to comment on them.	S-T, T-S	**5**: The students seem to be very engaged, and think that it is amusing to see photos of each other on the smartboard.

The Structure of Elisabeth's Teaching

As seen in Table 9, Elisabeth's module consisted of several relatively short parts that lasted for no more than 30 minutes. This made the lesson appear very dynamic as new activities were continuously being introduced.
Elisabeth used all of the phases of the 6F-model, but because she had to earmark 30 minutes for the students to work on their reports, the phases did not appear in the conventional order as presented in Chapter 2.

In this case, the journal work should be seen as an explanatory phase, while the phase where the students created an overview of the electromagnetic spectrum can be seen as a phase where the students extended the conceptual knowledge they had acquired in the previous module. This is further supported by the fact that the film that the students watched in this phase, was not meant to have an engaging effect, but rather to give a short summary of what the students had learned about the electromagnetic spectrum.
The next four stages of the lesson can then be seen as another 6F cycle where the phases Elicit, Engage, Explore and Explain occurred in the conventional order.

During almost the entire module, Elisabeth would continuously circulate around in the classroom and give feedback to the students, why student-teacher and teacher-student feedback was taking place in almost the entire lesson. However in the exploratory phase where the students used the infrared cameras, the students were to a high degree left to them selves, as Elisabeth had to answer some questions from some of the students regarding their reports. Figure 7 illustrates the amount of time Elisabeth spent on the different phases in the module.

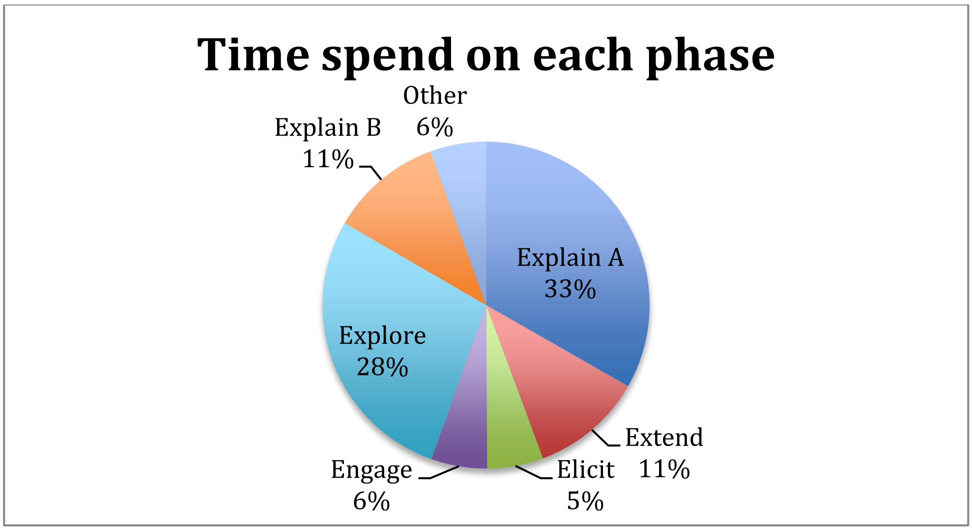

Figure 7: Time spend by Elisabeth on the different phas

Level of inquiry

The level of inquiry in the module is difficult to classify, because of the variety of phases that Elisabeth made use of.
The first exploratory part of the module, where the students worked on their reports based on experiments from previous module, can thus be classified as structured, as the reports were based on questions that Elisabeth had fabricated. Conversely the exploratory phase, where the student played around with infrared cameras, can be classified as extremely open, as Elisabeth did not give the students any particular instructions, and in general did not provide much feedback to the students.

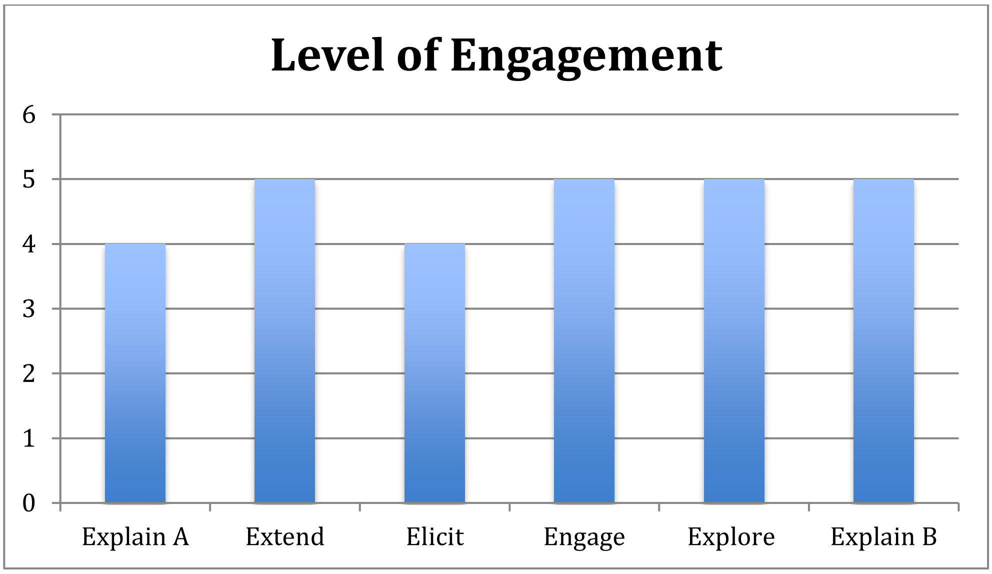

Figure 8: Elisabeth's students level of engagement in the different phases of the module

Student engagement

The students' level of engagement seemed to be very high in most of the module. I thus never observed more than a couple of students, not paying attention to the activity that was playing out, at the time.
The level of engagement was nevertheless highest, when Elisabeth showed short video clips, when the students were playing around with the thermal cameras and in the last explain-phase when Elisabeth showed some of the photographs, that the students had taken, on the classroom smartboard, and asked them to explain anomalies.

In summary Elisabeth's teaching was put together by several short phases of the 6F model, in which the students worked in different constellations.
The teaching was to a large degree student centred and the students were among other engaged by videoclips and by being allowed to 'play around' with thermal cameras, which is reflected by the high level of student engagement

Descriptive analysis results

Structure

The three observed modules were, for various reasons structured in different ways. The organisation of Micks teaching was, thus influenced by being a linkage between two different topics and 6F-cycles, while Charlie's module was centered on one difficult experiment that lasted for most of his module. Finally, Elisabeth's teaching was divided into several smaller phases, where the students worked in many different ways, without making an actual experiment.

In spite of the differences in how the teaching was organized, I noticed several parallels between the modules, as all of the three observed teachers, to varying degrees, had used the 6F-model as a template when planning their teaching.
As a result I detected 6F-phases in all of three observed modules, however Interestingly, none of the teachers had chosen to incorporate a full 6F cycle in their modules, as each teacher had planned their 6F-cycle to last for two modules or more[16]. This affected what phases the teachers made use in the modules that I observed, which was exemplified by Micks teaching, where the first part of the teaching was made up of an extension-phase, while the second part was largely devoted to an explorative-phase centered around a new topic (Figure 3).

In relation to this, it should be mentioned, that all of the teachers had planned their 6F-cycles so that the exploratory phase preceded the explanatory-phase, which, as mentioned, can be considered a fundamental aspect of inquiry-based teaching.

Elisabeth and Charlie's teaching was, on the other hand, somewhat influenced by school policies, which affected parts of their teaching.
Charlie's teaching was thus to some degree predetermined as a result of his schools decision to unify all chemistry C-level curricula, which influenced the level of inquiry he was able to implement during the experiment that I observed, while the structure of Elisabeth's 6F-cycle was distorted, as she had to let her students do a written assignment during her module. The written assignments in both Elisabeth and Charlie's lesson were, however, related to the rest of the classroom activities, why they can be interpreted as explain-phases.

To give an overview of which 6F-phases I detected in the three observed modules, these have been presented in Table 10.

[16] Even though Elisabeth had incorporated all six phases in her teaching, I did not witness a full cycle, as her elaboration-phase was related to the previous lesson.

Table 10 The observed 6F-phases in the three modules

The teachers use of 6F-phases						
	Elicit	Engage	Explore	Explain	Extent	Feedback
Mick	✓	-	✓	-	✓	✓
Charlie	✓	✓	✓	✓	-	✓
Elisabeth	✓	✓	✓	✓	✓	✓

Apart from the high degree of student centredness and somewhat arbitrary order in which the teachers implemented the 6F-cycles, I also noticed some similarities in the amount of time that was spend on each 6F-phase.
Most time was thus devoted to the exploratory phase in all three modules while significant time was also spent on the explanatory phases. This is illustrated in Figure 9, where the average share of each module that was spent on the various phases, is calculated. In average, the three teachers spend 32,5 percent of their modules letting their students explore in various ways, while 25,5 percent of the time was devoted for explanation. In continuation of this, it should be mentioned that Micks teaching did not at all include an explanatory phase, had it done that, the average time spend on explanation would presumably have exceeded the time spend on exploring. In relation to this, the activities in the explanatory phases in both Elisabeth's and Charlie's lessons were almost entirely made up of the students writing journals, I thus only witnessed one oral explanatory-phase in all of the three modules. This was located in the end of Elisabeth's module, and lasted for approximately 10 minutes.

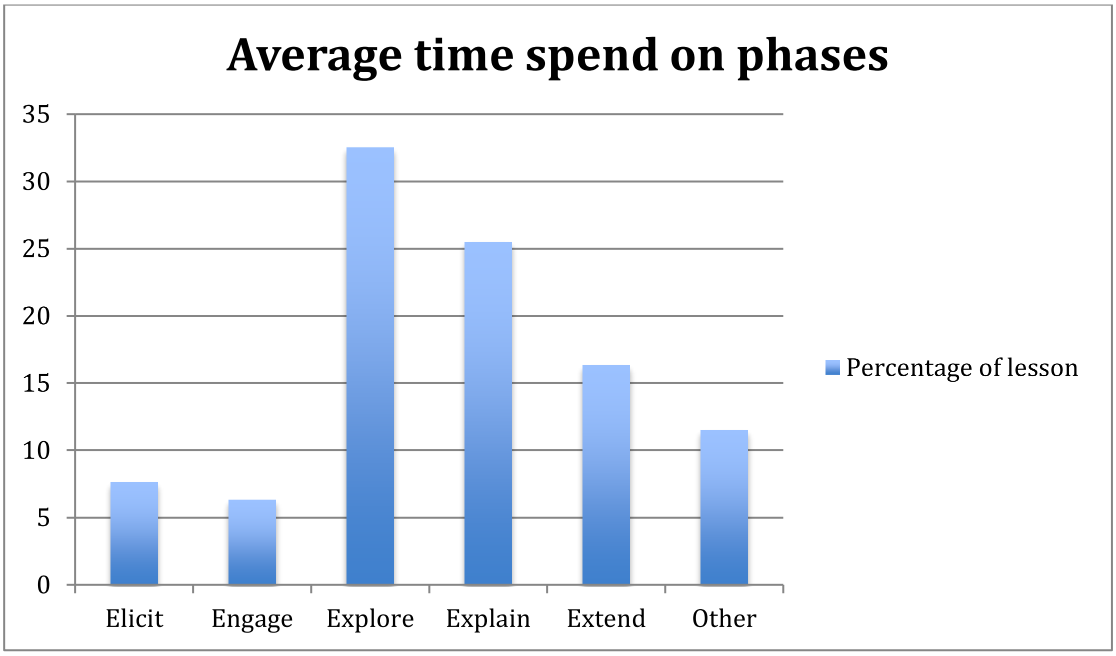

Figure 9: Calculated time spend on the different phases of the 6F model.

Level of engagement

As I indented to observe if inquiry-based teaching has a motivating effect on students, I monitored and classified their level of engagement during the different stages of the observed modules. The classification was, as mentioned, based on the percentage of the students who seemed to be engaged and focused on the teaching during a given phase, and valued from 1 to 5.

This method was chosen because of its simplicity but naturally it also had some important biases, as an example I had to simplify my classifications during time-consuming phases. This, among other, happened during Charlie's long exploratory phase where the students were very motivated in the beginning and then, as they gradually completed the experiment, lost interest. The disadvantages of my methods are further reviewed in my discussion.

According to Figure 10, which illustrates the average degree of student engagement during the different phases of the three modules, the level of engagement was at a relatively high level throughout all of the observed lessons. Overall the highest level of engagement was, however, detected in the exploratory phases, while the students also seemed engaged in the extend-phases.

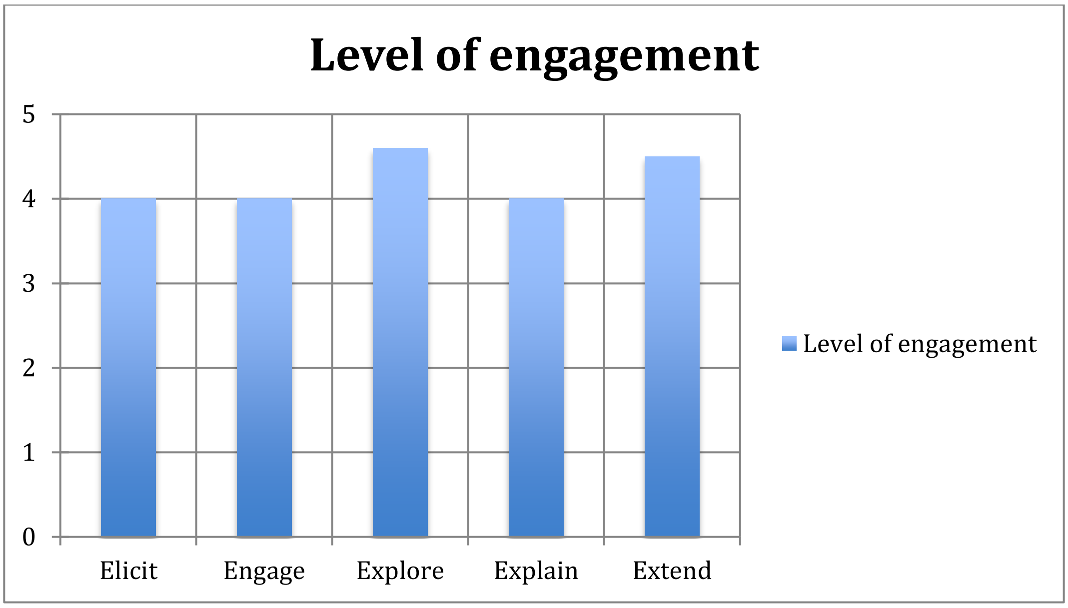

Figure 10: The average level of engagement in the different phases of the observed modules

Thematic analysis

In order to identify and extract information from my interviews, I have conducted a thematic analysis, which can be described as a systematic review of a qualitative dataset, where the researcher identifies different themes that will help answer his, or her, research questions.
The thematic analysis can be described as one of the most common approaches to qualitative data analysis (Bryman 2012 p. 580), but in spite of its apparent frequency of use, it is a remarkably underdeveloped method, as researchers still disagree about its exact and procedures (Ibid).
To stay on safe ground, I have chosen to imitate the framework given by Braun & Clarke (2006), to help organize my data and extract key information that will help answer my research questions.

Theoretical background

When conducting a thematic analysis, a researcher essentially can choose to follow one of two opposing analytical pathways, in order to identify the themes he, or she, wishes to use (Braun & Clarke 2012 p. 57). The researcher can, thus, apply an inductive approach, which is a bottom-up approach that is driven by what is in the data, which means that the themes derive from the content of the data themselves. Or he can chose a deductive approach which, on the other hand, is a top-down approach, where the researcher analyses the data with a distinct focus in mind and, consequently, interpret the data in accordance with his own ideas and thoughts, and tries to fit it into already determined categories (Ibid).
The two approaches hold different analytical advantages, as the former tends to result in a broader and more nuanced representation of the data, while the latter results in a more detailed description of a narrower extract of the data (Braun & Clarke 2006).
In this study, I have applied a deductive approach as I systematically have identified themes that would relate to my research questions. I have thus mainly looked for themes regarding science teacher's perceptions of and use of inquiry-based teaching, and in addition, what advantages and disadvantages they believe the instructional method holds.

In continuation of this, it can be discussed if it is not impossible to make a purely inductive analysis, as it is always difficult not to interpret ones data in the light of predefined ideas and concepts. This, at least, has been the case in my study, as my data has been shaped by my interview-guide, which again has been formed by my research questions that was thought out, when I first started thinking about the focus of this thesis.

Analytical procedure

As mentioned, I have chosen to imitate the procedure presented in Braun & Clarke (2012, pp 60-69) in order to extract information from my interviews and to answer my research questions.
In their framework, Braun & Clarke divide the process of a thematic analysis into six phases that must be followed, in order to obtain a high degree of validity in an analysis; these six phases can be seen in Table 11.
I have roughly followed all of the phases, but I do, however, slightly differ from Phase 1, as there was no need for me to transcribe my interviews.

Additionally it should be mentioned that, I have had one of my fellow thesis students, who are also familiar with Inquiry-based teaching, analyse parts of my data, in order to look for themes with relevance for my research-questions and in general add validity to my analysis and my findings.

The Data set used in this analysis consists of the six interviews that I have held with science teachers from different schools, and the informal conversations that I have had with several students, during my classroom observations, about what they thought about IBSE[17].

Table 11: A summary of the six phases of a thematic analysis based on Braun & Clarke (2012)

Braun & Clarkes six phases of a thematic analysis
1. Data familiarisation In the first phase the researcher transcribes the data, reads the transcripts and makes notes of initial thoughts. In this way he gets familiar with the data.
2. Code generation In the second phase, points of interest within the data are coded in a systematic manner, by the researcher, in order to organise it.
3. Searching for themes The generated codes are then arranged into larger provisional themes, which contain all data pertaining each theme.
4. Theme review After having extracted the data and divided it into themes, these are compared to the coded data and the data set as a whole to check their validity.
5. Defining themes After the themes have been reviewed they are named, defined and analysed.
6. Report Finally data extracts are selected in order to support each theme, and the analysis is written.

[17] In many circumstances, I could not ask the students about what they thought about IBSE, as they would not understand the question, as a result I asked them about what they thought about working in groups, making experiments and so forth.

I began my analysis by listening to the interviews, in an attempt to get familiar with the data. While I was working my way through the interviews, I took notes and logged, when in the interviews the teachers talked about specific subjects. After having done that a sufficient amount of times, I ended up with twenty-five codes (see FrontPage) that I applied on my data in order to organise it. I then put together the codes that had roughly the same content, which formed the foundation for the following eight provisional themes[18].

- **Definition:** Teachers define inquiry-based teaching and explain its nature, the role of the students and the role of the teacher
- **Planning:** Teachers explain how they usually plan their lessons, and talk about where they find inspiration.
- **Structure:** The interviewed teachers explain how they typically structure their lessons and use the 6F-model.
- **Perceptions:** The teachers express what they think about inquiry-based teaching.
- **Advantages:** Teachers talk about the advantages of inquiry-based teaching.
- **Challenges:** The teachers explain which challenges they face when using IBSE,
- **Feedback:** Teachers describe the importance of feedback in inquiry-based lessons
- **Motivation:** Teachers describe how inquiry-based teaching engages their students.

After I had created the eight themes, I reviewed the data once again to investigate, if it contained enough evidence to substantiate my analysis and arguments. It was in this phase that I had my fellow thesis student listen to two of the interviews, and look for themes that would fit my research questions. In all she came up with the following eight themes: Planning, advantages, disadvantages, scientific literacy, the 6F-model, perceptions of IBSE, learning outcomes and motivation.

These more or less corresponded with, or could be adjusted so that they would fit into the themes that I myself had created. As an example, my fellow thesis student had found that the teachers, in the two interviews she listened to, expressed that IBSE has the potential to increase the scientific literacy of students, and thus classified scientific literacy as a theme. I, however, believe that this is a topic that fits in to the overall theme of advantages of IBSE. Likewise she had chosen to interpret the 6F-model as a general theme, which I believe is a part of an overlying theme that I have called Planning.

[18] The process of coding is attached as Appendix F.

As a result, I didn't use any of the specific themes that my colleague suggested, but as we discussed the interviews, I nevertheless did, realize that it would make sense to put together the phases planning and structure, as they essentially cover the same aspects. Additionally I chose to merge the themes Feedback and Challenges, as the teachers would, to some degree, perceive it as a challenge to give feedback, especially in classrooms with many students. In the same way, I merged the themes motivation and advantages and finally I decided to put together the phase's definition and perceptions as I recognized that the way people define something is often closely related to the way they perceive it.

I thus ended up with the four themes: Perceptions, Planning, Advantages, and Challenges, which I think covers the scope of my study.

Thematic analysis Results

In this section I present and describe the four themes that I have reached through my thematic analysis. The presentations are made up of a short definition of each theme, a summary of my findings and quotations[19] from the interviews that illustrate my points, which are then discussed in the following chapter.

Perceptions

The way teachers perceive inquiry-based teaching, naturally derives from their own experiences with the teaching method; successes as failures, and further relates to how they use it in practice. Therefore, it is logical to begin the presentation of my results with this theme, before moving towards the related themes, Planning and Advantages and Challenges of IBSE.

As I, as mentioned, believe that there is a close relation between how a person perceive or understand a given concept and how they define it, I asked all of the six teachers to define IBSE for me. In general they were all able to define the teaching method and, none were in doubt of its overall structure and nature and what it implies of the students and the teacher. This is illustrated by John, Charlie and Elisabeth, who defined Inquiry-based teaching in the following ways:

(A) "For me inquiry-based teaching is all about the students creating hypotheses and figuring out how to explore them in order to reach conclusions that can answer these hypotheses" (Interview with John. 06:35 min.).

[19] Each quotation has been given a letter from A-W, which makes it easier for me to refer to it in the discussion. Furthermore, I have noted the exact time of the interview the quote was stated.

(B) “The central part of inquiry-based teaching is to take point of departure in the students curiosity, and then let the students explore new concepts in a way that is somewhat unsupported. The important thing is not to reach the right conclusions, but rather that the students get to use the true scientific methods and try to test hypotheses” (Interview with Charlie. 11:45 min).

(C) “In inquiry-based teaching I, as a teacher, don’t have to do the explaining as it is the students themselves who has to reach some conclusions by asking questions and exploring them. My role as a teacher is thus retracted as I, to a higher degree, takes on the role of a coach or a guide” (Interview with Elisabeth. 11:42 min).

The interviews thus indicated that all of the six informants had a fundamental knowledge about the nature of IBSE and that they all understood how to use it,

When asked more specifically about how they felt about using IBSE in practice, all of the six teachers indicated that they not only actively use it frequently as a way of teaching, but that they also perceive it as a valuable addition to their pedagogical toolbox, and that they moreover have the tendency to use 6F-phases in units or modules that are not necessarily inquiry-based.

This was illustrated by John and by Mick, who said:

(D) “Normally I use the 6F-model to systematize my inquiry-based biology lessons, and I always consider that my modules have to begin with some sort of engaging activity. Additionally I usually design the lessons so that the students have to do some kind of research” (Interview with John. 08:20 min.)

(E) “You can easily use parts of the 6F model in units that are not necessarily inquiry-based. For example, you can have an eliciting and an engaging phase without making an experiment, as it is not always that you can fit an explorative phase into your lesson” (Interview with Mick. 08:35 min.).

During the interviews the teachers presented me with several explanations as to why they perceive IBSE as a useful pedagogical tool. I shall investigate these reasons more thoroughly in the section about the advantages of IBSE. But, as the way teachers perceive IBSE is so closely related to their experiences with the teaching method, the two themes are in many ways entangled and hard to separate. As a result, I have chosen to finish this section about perceptions, with a quotation by Anne, which not only encapsulates the general positive attitude towards the teaching method and its nature, but also clarifies one of the reasons as to why the teachers enjoy using it in their classes:

(F) “I like inquiry-based teaching as it creates an interest for the subject as the students can see that it can be relevant in their everyday lives, at the same time it creates unity and good relations as the students are working together in order to figure things out” (Interview with Anne. 21:42 min.)

In summary it seemed from the statements they made, that all of the teachers, not only, are fully familiar with IBSE as a teaching method, but more importantly, that they perceive it as a valuable pedagogical tool that they like, and are comfortable in using. The teachers thus not only use the 6F-model as a tool when planning their inquiry-based lessons, they also incorporate phases from the 6F-model in units that are not necessarily inquiry-based.

Planning

In this theme I look into how the interviewed teachers in general plan their inquiry-based lessons, and what considerations they make when doing so. The theme is closely related to my classroom observations and as a result, it elaborates on some of my findings from the descriptive analysis.

In general, all of the teachers expressed that they would often use the 6F-model to structure their inquiry-based units, but that they had different preferences as to how they would do so. Some would thus follow the 6F-model more by the book than others, while the teachers preferred length of the 6F-cycles also, to some degree, varied depending on which topic they were teaching, none of the teachers did, however express, that they prefer to do a full 6F-cycle in a single module, instead their preferred length of a cycle seemed to be approximately 2-3 modules. This was illustrated by Mick who said:

(G) "I don't have the time to do a full cycle in every module, as it would make the teaching to conclusive and compressed in relation to what I sometimes want it to be. As a result I prefer longer cycles where the students have time to immerse themselves in the subject." (Interview with Mick 08:15 min.)

In relation to the basic composition of a 6F-cycle, all of the teachers importantly expressed that it was essential to do the explorative phase before the explanatory phase in a 6F-cycle. But when asked more specifically about if there were any phases in particular that the teachers would use more frequently than others, I noticed that there was a tendency that the teachers would almost always include some sort of engaging-phase into their teaching.

In fact, they all seemed to be very committed to creating education that would have an engaging effect on their students, which was something that they felt had a positive effect on the students' motivation and on the teaching in general. This was both expressed in the way that the teachers choose to structure their lessons, as all of them indicated that they preferred to include small phases that would allow their students to stay curious and active throughout the modules, which was illustrated by the observed teaching in both Mick and Elisabeth's modules.

But it was also expressed in the content of the lessons, as most of the teachers indicated that they would often try to modify the topics, into something the students were familiar with, so that they would find it easier to relate to the subjects. This was illustrated by Elisabeth, who impressively had taken an entire unit about the properties of light and altered it, so that it got an underlying STARWARS theme.[20]
She explained the reasoning for this in the following way:

(H) "I feel that the students think that it is a bit silly when I introduce a unit with a STARWARS or "Bamses Billedbog" theme, but in some way, they tend to be more prone to remembering the conceptual knowledge, if they can relate to the theme. Therefore I often try to make my teaching relatable for the students. This is however, easier in some topics than others" (Interview with Elisabeth. 19:16 min.)

In general the teachers found inspiration to plan their lessons from many different sources. They would, among other things, use Facebook groups for science teachers and online learning portals such as Clio, but most of their inspiration did, however, seemed to be found within the four walls of their schools, as the teachers expressed that they would often exchange ideas and course plans with their colleagues.
This is interesting as all of the teachers, additionally, expressed that they did not have the impression that Inquiry-based teaching was something that their colleagues would use, further they expressed that they didn't have the impression that their schools had any policies or guidelines for the implementation of IBSE.

The teachers' planning was, to some degree, influenced by different external conditions that they had to take into account when preparing their lessons.
As an example Elisabeth would usually incorporate two 6F-cycles in a unit that typically lasted for six modules. But the structure of these cycles was partly affected by the fact that she had to let her students write a report during the class, which explains why the module that I observed, peculiarly, started with a thirty minute long explanatory phase, and not with an eliciting or an engaging phase.

In the same way, the level of inquiry in Charlie's module, was affected by the fact that the academic level of his students was to low to really comprehend the experiment that they were doing, which was an experiment that Charlie's class,

[20] An excerpt from the teaching plan for Elisabeth's starwars themed unit is attached as Appendix G

had to do, as his teaching in Chemistry C-level was coordinated with the other C-level chemistry classes at his school.

Finally the planning of Anne's teaching and her use of the 6F-model was also to some degree affected, as it was the policy of her school that a unit of teaching is composed by no more than six modules.

The limitations caused by the varying procedures of their schools, did however not seem to bother any of the interviewed teachers, who essentially seemed to pay most of their attention to the content and methods of their teaching, rather than on the limiting effects of school politics.

In summary it seemed that all of the teachers frequently use the 6F-model when planning their teaching. In addition I got the impression that the teachers in general emphasized that their teaching was engaging, so that their students would stay motivated throughout the teaching.
This was both expressed in the way they composed their lessons, as they would incorporate many small phases that would allow their students to stay active, but also in the content of the lessons, as the teachers would often try to make the subjects relatable for their students.

Advantages

The previous two sections have illustrated that all of the six interviewed teachers frequently implement inquiry-based teaching in their teaching practice. In this section I seek to explain why, as I will now investigate the experienced benefits of the teaching method.

Motivation

In general the six teachers expressed that IBSE, from their point of view, holds advantages ranging from the social (quotation F), to the more cognitive and methodological. The most frequently mentioned advantage was, nevertheless, that the teachers find that IBSE has a motivating effect on their students, as this was something that all of the teachers agreed upon.

Overall, the teachers believed that IBSE has a motivating effect, as a result of its student centred and engaging nature, which allows students to explore topics in an active manner, this was illustrated by John who said:

(I) "I experience a lot of motivation when the students themselves help to create the experiment and then implement it. It is not because it is fundamentally different compared to if I had created it, but when the students themselves are allowed to make some decisions, it has a great motivational effect" (John 18:56 min.)

In addition to this, both Anne and Elisabeth, interestingly, expressed that they felt that IBSE had a positive impact on the academic inequality of their classrooms as they had experienced inquiry-based teaching to have a motivating effect that would increase the self confidence of especially the academically weaker students, as it tended to be this group, in particular, that would normally be engaged, if the teaching was on a level of abstraction that they could relate to.

(J) "The intelligent students always succeed no matter what kind of teaching they face, but then there is this big group of average students, this group is often engaged if they face some topics from their own lives that they can relate to, as this gives them some sort of confidence" (Interview with Anne 26:15 min.)

In relation to this, Anne further pointed out that she thought that the dynamics that appear when students do group work, also, in its own way, have a motivating effect on students, which the following quotation illustrate:

(K) "In traditional' teacher centered teaching' it is a possibility for many of the students to hide behind their computer-screen, but my experience is that if students are working in a group, they feel some obligation towards each other, as the social relations between the students are very important to them" (Interview with Anne 31:44 min.).

It is, of course, difficult to tell if the teachers' conceptions regarding the motivational effects of IBSE are correct or not. In an attempt to examine this, I talked to several students in the observed classes[21], to hear what they had to say about group work and doing experiments.
All of the students unanimously expressed their satisfaction with the workform, and although the answers they gave me naturally varied, they were all positive, and essentially built on the same arguments.
The following three quotations to some degree summarize what all of the students told me.

(L)"I like this form of work because it is better than reading and listening to the teacher" (Student from Micks class)

(M) " Its nice to do experiments because you get to use your own hands and you can see what happens with your own eyes" (Student from Charlie's class)

(N) "It is more fun and when we work in groups, the time flies by" (Student from Elisabeth's class)

Scientific Litteracy

[21] In all I talked to 16 students, somewhat equally divided between the 3 classes.

Overall, it seemed that the teachers emphasized that their students learn the scientific theory and methods of their subjects, and besides accentuating the motivating effect of IBSE, some of them additionally highlighted that inquiry-based teaching, in their eyes, is more method orientated than other ways of teaching, and as a result, to a higher degree enhances the scientific literacy of the students. As an example Jeff said:

(O) "Inquiry-based teaching may not cover the same amount of the syllabus as normal teaching does, but conversely when using IBSE the students really get an in depth knowledge about the subject being taught and their scientific competencies are trained in an authentic way" (Interview with Jeff 25:36 min.).

In the same line, Mick explained that he, not only thought that the method-orientated nature of IBSE gives his students some sort of scientific literacy, but that it also eventually teaches his students to think independently in relation to science related activities.

(P) "It is my experience that when I use inquiry, my students often becomes distressed, when they don't know what to do. My students are extremely dependent on others, and I think that inquiry definitely can change that" (Interview with Mick 13:30)

In depth knowledge

Last but not least, some of the teachers additionally mentioned that they felt that when they used inquiry-based teaching, their students to a higher degree were prone to remember what they had learned. This was among other mentioned by Charlie:

(Q) "When it is the students who do the exploring and independently reach the conclusions, I believe that the knowledge they gain is more permanent than if I had just presented it to them" (Interview with Charlie 17:55 min.).

In summary: When I asked about the benefits of inquiry-based teaching, all of the teachers seemed to agree that student motivation was a major positive outcome of the teaching method. In addition the teachers also expressed that IBSE provides students with a more in depth conceptual knowledge and at the same time creates good relations in the classroom. Finally some of the teachers emphasized that IBSE holds the potential to affect the confidence and motivation of, especially, the academically weaker students.

Challenges

In the previous paragraphs we have seen that the six interviewed teachers regularly use IBSE in their teaching, and that they, moreover, experience several benefits when using the teaching method. The teachers did, nevertheless, also mention that they have experienced various challenges when teaching inquiry-inspired lessons; in this paragraph I examine and summarize these.

Time

The most frequently mentioned challenge of IBSE was, by far, that it generally is a time consuming way of teaching. This should be understood, both in relation to the overall official time requirements, set by the ministry of teaching and indicated in the curricula for the individual subjects, as explained by Mick (Quotation R). But also in relation to the individual classroom, where the amount of students, makes it difficult for the teacher to be able to reach and give feedback to all of the students, as exemplified by Elisabeth (Quotation S)

(R) "If you want to do an authentic inquiry-based lesson, it takes time. This is problematic if you look at the overall time requirements set by the ministry of teaching. Each class has 80 biology modules in a year, but then they also have to do other stuff, fieldtrips etc. (...) At the same time, I have to cover a curriculum, so I often have to choose to cover some of the curriculum less thoroughly in order to make a proper inquiry-lesson" (Interview with Mick 15.06 min.).

(S) "The fact that there are 28 students in one class, makes it difficult for me to reach everyone and answer everyone's questions. (...) But then I use Menti[22] or make a brainstorm, so that we can talk about what happened in the experiment" (Interview with Elisabeth 31.16 min.).

Planning and level of inquiry

Some of the teachers additionally expressed that they thought it was easier to plan their teaching in accordance with the overall syllabus and the final examination and in some ways defend their choices, when using a traditional blackboard way of teaching compared to when using inquiry, because of inquiry-based teaching's somewhat unpredictable and time-consuming nature.

In relation to this, the level of inquiry was also a theme for the teachers when discussing the limitations of IBSE. Some of the teachers thus felt that it could be challenging to implement completely open inquiry-lessons if the academic level of their student's wasn't sufficient, this was among other illustrated in Charlie's lesson, where he had to turn his experiment into a cookbook-exercise so that all of his students would be able to complete it.

[22] Mentimeter is a digital tool for making brainstorms. As an example I have used it to create the front-page of this thesis.

In the same way, John described that it could be challenging for him to give to much freedom and responsibility to his students in an exploratory situation, as he never really knew if the experiment would then turn out positively or negatively.
Interestingly however, both of the teachers seemed to have accepted these issues, as john explained that he thought that it, in the end, was worth it, as he concluded that the benefits of inquiry was greater than the disadvantages (Quotation T). Charlie, on the other hand, had simply altered his approach to IBSE, as he would spend more time in the Elicit-phase, when teaching academically weaker classes, as he believed that it was in this phase, in particular, that he could provide his students the scientific language that they needed in order to comprehend the difficult experiments (Quotation T).

(T) "It is difficult to confer freedom and responsibility to the students. If they are not really interested in working, then I end up with some of the groups who don't get anything done. But I think that this is acceptable, because when IBSE works, the students are very engaged" (Interview with John 21.42 min.)

(U)"The 6F-model is structured so that it is the students who explore, but my impression is that the Elicit-phase plays a big part in chemistry on C-level, as the students lack the correct language. Therefore I often emphasize the eliciting phase, where I present the theme of the day" (Interview with Charlie 02.30 min.)

Materials
When I asked the teachers, if lack of materials was a limiting factor for them, I interestingly received opposing answers. Mick, Elisabeth and Jeff thus answered that they, to some degree, could use more lab-equipment, while Charlie, John and Anne felt that what they had, was sufficient.
In general the teachers answers were relatively concise and characterized by specific materials that they wanted, but in quotation W, John explains the reason why he thought that he didn't need additional materials, in a thoughtful way.

(W) "I have experienced that it is often easier to do inquiry with simple experiments and few materials (…) when the experiment to a high degree depends on materials, the students have to understand the equipment, and they have to use it correctly, with the result that the experiment gets locked, as the students cannot make their own hypotheses". (Interview with John 24.12 min.)

In summary
In general, the challenges experienced by the teachers, when implementing IBSE were relatively individual. All of the teachers did however mention that time, for them, was a limiting factor. The teachers thus expressed that it was easier for them to cover their curriculums, if they applied teacher centered teaching.

Additionally they expressed that it was a challenge for them to provide feedback to all of their students, when doing inquiry in classes with many students.

7. Discussion and Recommendations

In this chapter, I combine and discuss my findings from the two different analyses. I begin by discussing my results in relation to my research questions. This is followed by a section, where I discuss how the Department of Science Education, can adapt their course, in order to address the challenges faced by newly educated science teachers when they enter the school system. Finally I provide some conclusions.

Discussion of Research Questions

Research Question 1: How do newly educated science teachers, from the University of Copenhagen, understand and perceive inquiry-based teaching?

The qualitative basis for answering this research question comes from the thematic analysis of my six interviews. Here I found that, all of the interviewed teachers not only possess a detailed fundamental understanding of what inquiry-based teaching is, they also perceive IBSE as a valuable pedagogical tool, that they enjoy using in practice, (which they all claimed to do on a regular basis).

To be honest, this did not come as a big surprise to me, as each teacher had participated in the Advanced Methods of Teaching Science Course, where IBSE is a central theme. Furthermore five of the six interviewed teachers revealed to me that they had written their own theses at The Department of Science Education, why it is fair to assume that they must have a fundamental interest in didactics and instructional methods.

It did, on the other hand, come as a surprize to me that the teachers additionally incorporate phases and principles from the 6F-model into lessons, that cannot necessarily be characterized as inquiry-based, where especially the engaging-phase is often being used. This indicates that the teachers are comfortable in using the 6F-model and that they particularly have adopted the principle of creating teachable moments.

Conversely, none of the teachers expressed that they would often apply, for instance, an extend-phase in other teaching-situations, which is interesting, as this could suggest that the teachers does not, to the same degree, emphasize the importance of extending the newly achieved knowledge of their students, in the same way as they emphasize the importance of engaging them.

There may be many reasons for this; perhaps teachers find it easier to incorporate engaging phases into their teaching, as these are often comprised by short films and other easily manageable contents, or perhaps teachers find it difficult to think of new and alternative situations into which they can deploy the newly acquired knowledge of their students. From a personal point of view, I have certainly always found this to be challenging.
Unfortunately, at the time that I conducted the interviews, I did not realize the significance of this, which explains why I did not put further effort into investigating why teachers apparently would favor the engage-phase over other phases.

All things considered, I find that the interviewed teachers not only have a detailed fundamental knowledge about IBSE, but that they also perceive it as a useful pedagogical tool that they enjoy using. In addition, based on my interviews it would seem that the teachers especially have adopted the concept of engaging their students, which opens the question of why they don't, to the same degree, apply other phases of the 6F-model, such as the extending phase, in teaching that is not necessarily inquiry-based.

Research Question 2: How does the implementation of IBSE take place in practice?

- **To what degree does the teachers use the 6F learning cycle in their teaching?**
- **To what extent are newly educated science teachers able to implement IBSE into their teaching?**

Inquiry-based teaching, as Harlen (2004) stated, is a teaching method that can take on multiple forms, depending on factors such as the teaching style of the individual teacher, the academic level of the students, the classroom chemistry, the teachers beliefs and so forth, I have found that it is difficult to provide a generalizable answer to, how the implementation of IBSE takes place in practice. My own classroom-observations reflect the diversity of the teaching method, as I observed three interpretations of IBSE that were designed and structured in very different ways, involving different levels of inquiry and a variety of different classroom-activities.

In addition to this, I got the impression from the interviews that I have conducted, that the way teachers implement IBSE, varies in accordance to the abovementioned factors and especially to the teaching style of the individual teacher. This was among other exemplified by the difference between Mick's and Elisabeth's teaching, as Mick preferred extensive 6F-cycles with long phases that would allow his students to immerse themselves into the topic, while Elisabeth, on the other hand, preferred to incorporate many short phases, which would keep her students active and engaged.

Even though it is hard to generalize how IBSE is implemented in practice, all of the teachers did however, as mentioned, share a common understanding of the teaching method, as they unanimously expressed that they always use the 6F-model as a tool, when structuring and planning their inquiry-based lessons, and additionally emphasized that it is essential that the explorative phase, in a 6F-cycle, is completed before the explanatory phase is commenced, and finally, that it is important that it is the students who complete the experiments, while the teacher scaffolds the activities. Therefore, although there may not be a definitive way in which IBSE is implemented in practice, it is, nevertheless, possible to identify some clear connections in how newly educated science teachers plan and implement inquiry-based teaching into their lessons, which are, more or less, always designed with the 6F-model as an underlying template.

The way that the teachers use and interpret the 6F-model does, however, differ, as some tend to follow it more rigorously than others. Once again Elisabeth's teaching serves as an example of the former, while Mick's serves as an example on the latter, as his module was divided by two different themes and two 6F-cycles, with the result that his module began with an extending phase and ended with an exploratory phase, and thus did not include an explain-phase.
Even Though Mick, in essence, followed the 6F cycle, his decision to end one cycle and begin another in the same module, could potentially have had a confusing effect on his pupils, and in the end, lower their learning outcome.

Based on the descriptive and the thematic analyses that I have conducted, it would further, seem that all of the six interviewed teachers, to a large extent are able to implement IBSE in their teaching practices. It is however, in continuation of the discussion about how teachers understand IBSE, important to raise the question, if whether the interviewed teachers use of the 6F-model in lessons that are not necessarily inquiry-based, potentially can mislead the teachers to think that their teaching automatically becomes inquiry-based, as long as they include phases from the 6F-model.

As an example, Charlie's lesson, which included the phases engage, elicit, explore and explain, but at the same time basically was a cookbook-exercise, cannot be characterized as inquiry-based. Charlie's explanation to his use of cookbook-exercises was, that he felt that he faced some difficulties when conducting difficult experiments in his chemistry C-level classes, as his students simply lacked the sufficient scientific language and knowledge to understand, what was going on in the experiments, which is a problem that many chemistry teachers experience (Persson 2017). Therefore he felt that he had to provide his students with some understanding about the experiment, so that they were able to complete it. In continuation of this, he further revealed that he would sometimes emphasize the elicit phase, as he felt that he could use this phase to provide his students with some basic scientific understanding, which potentially could be problematic, as the constructivist point of IBSE exactly is, that students have to imitate scientific practices, without having too much prior knowledge about the phenomenon that is being investigated.

The question is then, what Charlie could have done differently, in order to make the experiment inquiry-based? As explained, he had to do it, as his school has a policy that all Chemistry-C-level classes share the same curriculum, therefore he could not simply delay the experiment until his students had reached a sufficient academic level, nor could he lower the difficulty of the experiment.
Instead he could have transformed the experiment into a demonstration, where he was in charge of the execution of the experiment, while his students could observe, explain and interpret their observations. In this way, he would have been able to complete the experiment, while retaining the nature of IBSE.

Based on my findings, I conclude that, as a result of the diverse and open nature of IBSE, it is impossible to generalize how the teaching method is implemented in practice, as this varies from teaching situation to teaching situation. However, the teachers involved in this study, unanimously expressed that they would always, in some way, use the 6F-model when planning their lessons. The 6F-model can therefore be seen as an indispensable tool for the implementation of IBSE. The teachers additionally expressed that they would often implement inquiry-based teaching in their teaching practice. However, even though the teachers proved to have a deep fundamental understanding of IBSE, the teachers' perceptions of and use of IBSE, is ultimately based on their individual understandings, perceptions and beliefs, with the result that misunderstandings and misinterpretations of the teaching method sometimes occur when it is implemented in practice.

Research question 3: What benefits and difficulties do teachers experience when using IBSE.

a. Does IBSE have a motivating effect on students?

Overall, the benefits experienced by the teachers, were generally in line with what is mentioned in the literature. Several of the teachers, thus expressed that they felt that IBSE increases the scientific literacy of their students and provides them with in-depth knowledge and the ability to work independently, which is in accordance with Minner et al. (2010), Nielsen (2017), Frisdahl (2014) and Kruse (2013). In addition, all of the participating teachers expressed that they felt that IBSE has a motivating effect on their students, which is supported by, among others, Kruse (2013), Bentsen et al. (2009) and Wistoft & Stougaard, (2012). Finally, Anne and Elisabeth, pointed out, that they had experienced that IBSE especially engages the less skillful of their students, and levels out the academic inequality in the classroom, which is mentioned by Marshall and Alston (2014).

In an attempt to verify if IBSE, indeed, has a motivating effect, I talked to several students during my classroom-observations, and set up a simple way to measure the overall level of student engagement in the different phases of the classes that I observed. Overall, my observations (Figure 10) illustrate that the level of engagement was highest in the explorative and extending phases of the observed modules, which indicates that the students worked most actively when they were exploring. Quotation L, M and N, further indicates that the students prefer student centred activities over other forms of teaching.

The validity of my methods, and the statements made by the students can, however be discussed. First, the simplicity of the method that I used to measure student engagement with, during my observations, may have caused some biases. As an example the way that I measured the students' level of engagement, was because of its simplicity, especially in longer phases, not very illustrative as it became impossible for me to summarize all of the students' activities in a given phase with just a number. In continuation of this, it was difficult for me to know if the students were indeed working actively and paying attention, or if they were doing other things, which is an issue that I assume many teachers face on a daily basis. In addition to my own observations, the students' statements about working in groups must not be given to much value, as the students that I talked to, may have been affected by talking to me as a researcher, which can have influenced their answers.

In order to add a higher degree of validity to my data regarding student motivation, my methods and my entire study should probably have been significantly altered, and included, more observations as well as a more adequate body of quantitative data.

Measuring student engagement has, however, never been the central aim of this study, why I am satisfied with my data, which indicates that both teachers and students find inquiry to have a short term motivating effect. In continuation of this, it should be mentioned that, although my study indicates that students are engaged when doing inquiry, I am unable to conclude if inquiry-based teaching generates longer-term personal interest in natural science, and motivates them to a scientific career.

In addition to the experienced benefits of IBSE, the interviewed teachers additionally expressed that they face certain problems when implementing the teaching method in practice.
All of the teachers thus mentioned that they find that IBSE is more time-consuming, than traditional 'teacher-centered' or 'textbook-based' teaching, which among other is in line with Østergaard, Sillasen et al. (2010) and Kruse (2013).

As a result, the interviewed teachers expressed that they sometimes prefer 'teacher-centered' or 'textbook-based' teaching, as these methods are easier to design in accordance to the overall standards set by the Ministry of Education and the final examinations. The tendency to 'teach for the test' (Harlen 2007), is generally problematic, in relation to IBSE, as the teaching becomes directed towards the basic abilities and knowledge needed, by the student to pass the test, while other competencies, on the other hand, are neglected (Nordenbo et al. 2009).

In relation to the time-consuming nature of IBSE, several of the teachers additionally expressed that they find it difficult to provide valuable formative feedback to all of their students in inquiry-based lessons, as their classes are simply to big. This is, of course, problematic, as feedback is essential for the teachers' ability to scaffold the teaching for the individual student (Frisdahl 2014; Yin, Shavelson et al. 2008).

Furthermore, some of the teachers expressed that they sometimes find it hard to relinquish control, to the students during inquiry-based lessons, and that they need materials and equipment in order to implement IBSE. There were, however, different opinions about this, why I do not find these difficulties to be as significant as the teachers perceived lack of time and difficulties in providing feedback.

Based on my findings I thus conclude that the teachers experienced benefits and difficulties are in accordance with what I have found during my research. The teachers thus experience that IBSE motivates their students, levels out the academic inequalities of the classroom and increases the scientific literacy of students, while they on the other hand, believe IBSE to be a time-consuming instructional method, which is difficult to fit into the syllabus and overall teaching standards. Furthermore the teachers find it difficult to provide effective feedback to the students, especially in classes with many students.

Recommendations

Overall, the Advanced Methods of Teaching Science Course (AMTSC) meet the recommendations presented by Crawford (1999). As future teachers, throughout the course, are engaged in authentic inquiry-based situations, as well as they experience IBSE on fieldtrips and have extensive scaffolded practice with planning inquiry-based lessons (Crawford 1999). I have, nevertheless, found that newly educated science teachers experience certain difficulties, when implementing inquiry-based teaching into their teaching practice. Therefore, this section discuss, how The Department of Science Education can address these difficulties, by adding or improving a few focus points in the AMTSC curriculum.

The lack of time

As all of the science teachers involved in this study, expressed that they feel that inquiry-based teaching is difficult to implement and plan in accordance to the overall teaching standards formulated by the Ministry of Education, and in some cases, the policies of the individual schools, it is important that the future students at the AMTSC are provided with some strategies that can help them balance these influences.

It is already a major focus point, on the course, that students are taught how to transform 'traditional' teaching into inquiry-based lessons, which in theory should address the issue of how to design IBSE in accordance to the centralized teaching standards. In addition, students are trained in how to connect IBSE with the teaching standards, as they are forced to contemplate how the inquiry-lessons they design, during the course, can be related to the basic ideas and professional goal of their scientific subjects. My study and Charlie's experiences in particular, does nevertheless, indicate that teachers still find it difficult to do so in practice.

A way to address these problems could possibly be to, at a higher degree, problematize the issue during the course, which is not necessarily being done at the moment. As an example, the dilemma that Charlie faced could be transformed into an assignment, where the students at the course, in pairs or in groups, should discuss and find a solution to how Charlie could complete his experiment without downgrading the level of inquiry.

Another way to address the issue could be to invite a former student at the course, who now works as a science teacher, to hold a lecture about what it is like to do inquiry-based teaching, and what to be aware of when doing so. In this way, future teachers can get valuable information about what it is like to teach in science from a first hand source[23].

Focus on Feedback

Several of the interviewed teachers did additionally reveal that they find it difficult to provide formative feedback to their students, especially in large classes. This naturally calls for an increased focus on how to provide feedback, and perhaps an introduction of additional pedagogical techniques and interactive tools that can increase the competencies of future teachers, and make it easier for them to provide feedback.

Another way to address the issue would be, to put more emphasis on how to select materials and design lessons where feedback is easier to implement.

Materials

Even though it wasn't as significant an issue as the two abovementioned, some of the teachers expressed that they sometimes experience that they don't have the necessary equipment for creating inquiry-based teaching. Therefore, more could be done, during the AMTSC, in order to highlight the point, which was also presented by John, that it is often easier to implement IBSE with fewer and simpler materials. Furthermore the point could be raised, at the course, that the learning outcome of the students, not necessarily is increased in experiments with complicated equipment, as this potentially can affect where the students chose to focus their attention.

Extending the knowledge of the students

Finally, I found that the teachers in this study have the tendency to apply engaging phases in teaching that is not necessarily inquiry-based. This is of course very positive, as the effectiveness of engaged students has been documented by much research (Bybee 2015; Bass et al. 2009). Conversely, none of the teachers emphasized the importance of the extending phase, which could prove to be problematic, as research additionally points to the importance of learning how to apply newly achieved knowledge and skills in alternative situations (Bybee 2015).

As a result, attention must be paid to educating future teachers about the importance of extending student knowledge as well as providing future teachers with inspiration and ideas about how to design extending-phases.

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[23] They successfully do this in the didactics-courses on History (KUA), which is my second subject.

8. Conclusion

The aim of this study was illustrate how newly educated Danish science teachers understand, perceive and implement inquiry-based teaching in their teaching practices, as well as to examine what benefits and difficulties teachers experience, when doing so. Therefore, this thesis is meant to add to the body of research that seek to improve science teacher education and professional development. My approach was to interview six science-teachers in order to learn about their perspectives and experiences with the instruction method. In addition to this, I have observed three inquiry-based modules, in order to understand how IBSE is implemented in practice.

I have found that all of the participating teachers had an extensive knowledge about IBSE, and that they perceive it as a valuable pedagogical tool that they frequently implement in their teaching. Furthermore, the science teachers involved in this study revealed that they tend to implement phases from the 6F-model into teaching that cannot necessarily be characterized as inquiry-based, where the teachers, in particular, seemed to have embraced the concept of engaging their students.

Furthermore my analysis revealed that the way inquiry-based teaching is implemented in practice, varies due to factors such as, the individual teaching style of the teacher, the academic level of the students, the subject being thought and the teachers conceptions about inquiry, which is also indicated by other research (Crawford 1999, Keys and Bryan 2001, Harlen 2004). As a result it is difficult to generalize how IBSE is implemented in practice. However, as the teachers additionally unanimously expressed that they always use the 6F-model, when designing their inquiry-based lessons, the structure of IBSE in classrooms, can be considered to be in accordance to the 6F-model, which is considered an indispensable tool by the teachers.

The study further revealed that newly educated teachers generally believe that IBSE has a motivating effect, as well as it increases the scientific literacy of students and limits out the academic inequalities of the classroom, which is supported by much research (Minner, Levy et al. 2010, Kruse 2013, Marshall and Alston 2014). On the other side, the teachers experienced difficulties related to the time-consuming nature of IBSE, and how to provide feedback to students.

Therefore, I conclude that newly educated science teachers from the University of Copenhagen, have an extensive understanding of IBSE, and perceive it as a valuable pedagogical tool that they often apply into their teaching. However, in order to further improve the implementation of IBSE, more emphasis is to be put on educating future teachers in how to manage issues related to especially time, and how to provide feedback.

9. Future Perspectives

While my findings are not generalizable to an entire population of newly educated science teachers, and my study cannot be expected to provide ground-breaking results, considering its scope and duration, it can provide valuable information about a few beginning science teachers' experiences with IBSE, which combined with a growing number of case studies in science education, can provide valuable information that potentially, can improve future science teacher education.

It would, in relation to this, have been interesting to enlarge the scope of the study. A way to do this, would be, to include more newly educated teachers, or even experienced teachers, who have been introduced to IBSE via different professional development initiatives, to learn if they share the same understandings of, and experience similar benefits and difficulties, when implementing IBSE in their teaching practice.

Another way to do this would be to follow the participating teachers more closely over a longer duration, to capture more facets of their experiences with inquiry-based teaching, positive as negative.

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Appendix A: Teaching plan for the scientific introductory course at upper secondary schools.

Naturvidenskabeligt grundforløb – stx, august 2017

Identitet of formål

1.1 Identitet

Det naturvidenskabelige grundforløb udgør den gymnasiale introduktion til naturvidenskab gennem arbejde med grundlæggende elementer af naturvidenskab. Der lægges vægt på både den faglige bredde og det sammenhængende i naturvidenskaben. Udgangspunktet for naturvidenskabeligt grundforløb er aktuelle problemstillinger med et naturvidenskabeligt indhold, som bredt repræsenterer de naturvidenskabelige fag, og som giver mulighed for en undersøgende, eksperimentel og oplevelsesorienteret tilgang til omverdenen. I naturvidenskabeligt grundforløb kan fagene biologi, bioteknologi, fysik, geovidenskab, informatik, kemi og naturgeografi indgå.

1.2 Formål

Eleverne skal i undervisningen introduceres til naturvidenskabelige arbejdsformer, tankegange og argumentation. Eleverne skal ligeledes på elementært niveau kunne forholde sig til naturvidenskabelig videns muligheder og begrænsninger. De skal opnå viden og kundskaber om udvalgte naturvidenskabelige problemstillinger og deres perspektiver. Elevernes nysgerrighed og engagement indenfor det naturvidenskabelige område skal fremmes, ligesom naturvidenskabeligt grundforløb skal bidrage til såvel elevernes almendannelse som til afklaring af deres studieretningsvalg.

2. Faglige mål og fagligt indhold

2.1 Faglige mål

Eleverne skal kunne:

- Formulere og teste enkle hypoteser
- Gennemføre praktiske undersøgelser og eksperimenter såvel i felten som i laboratoriet under hensyntagen til sikkerhed
  Opsamle, systematisere og behandle data med brug af forskellige repræsentationsformer
- Anvende modeller, som kvalitativt og kvantitativt beskriver enkle sammenhænge i omgivelserne, og kunne se modellernes muligheder og begrænsninger
- Formidle et naturvidenskabeligt emne med relevante faglige begreber og repræsentationer demonstrere basal viden om naturvidenskabs identitet

og metoder og anvendelse af matematik indenfor naturvidenskab.

2.2 Fagligt indhold

Ved udvælgelsen af det faglige indhold i naturvidenskabeligt grundforløb lægges vægt på, at indholdet giver anledning til:

- x Samarbejde mellem de naturvidenskabelige fag
- x Eksperimentelt arbejde, såvel i Laboratoriet som i felten
- x Behandling af kvalitative og kvantitative empiriske Data
- x At opstille, anvende og fortolke lineære sammenhænge
- x At vise relevansen og anvendelsen af naturvidenskab i samfundet.

2.4 Omfang

Forventet omfang af fagligt stof er normalt svarende til 30-70 sider.

3. Tilrettelæggelse

3.1 Didaktiske principper

Undervisningen skal tage udgangspunkt i et fagligt niveau svarende til elevernes naturvidenskabelige og matematiske viden og metodekendskab fra grundskolen.

Det naturvidenskabelige grundforløb tilrettelægges som mindst to flerfaglige, tematiske forløb med afsæt i aktuelle problemstillinger med naturvidenskabeligt indhold. Forløbene inddrager tilsammen fagligt indhold fra mindst tre naturvidenskabelige fag, jf. pkt. 1.1. Undervisningen tilrettelægges, således at eleverne inspireres til at arbejde aktivt med problemstillingerne. Det eksperimentelle og undersøgende arbejde i såvel laboratoriet som felten skal stå centralt i undervisningen.

3.2 Arbejdsformer

Der skal vælges arbejdsformer, som bringer eleverne i en aktiv læringsrolle.

Elevernes eksperimentelle arbejde og feltarbejde skal udgøre en væsentlig del af undervisningstiden.

Mundtlig og skriftlig fremstilling indgår med henblik på faglig argumentation, formidling, forståelse og fordybelse.

Eleverne afleverer et antal mindre, skriftlige produkter, som tilsammen dokumenterer arbejdet med de faglige mål. Produkterne samles løbende i en portfolio, som danner grundlag for en individuel intern mundtlig prøve, jf. pkt. 4.

Ved afslutningen af forløbet udvælger eleven, med henblik på fremlæggelse ved den interne prøve, dele af sin portfolio, som viser arbejdet med de faglige mål. Udvælgelsen sker under vejledning.

3.3 It

Digitale værktøjer og ressourcer anvendes i undervisningen til dataopsamling, databehandling, graftegning, simpel modellering og skriftlig repræsentation af resultater.

3.4 Samspil med andre fag

Undervisningen i det naturvidenskabelige grundforløb skal koordineres med matematik.

4. Evaluering

Løbende evaluering Der foretages jævnligt evaluering med udgangspunkt i de skriftlige produkter for at vejlede eleven i det fremadrettede arbejde.

Afsluttende evaluering

Der afholdes en intern individuel mundtlig prøve af ca. 20 minutters varighed, hvor to af elevens lærere i naturvidenskabeligt grundforløb er til stede. Prøven afvikles i forbindelse med afslutningen af grundforløbet. Prøvegrundlaget er elevens portfolio jf. pkt. 3.2. Portfolioen skal være til stede ved prøvens afholdelse. Der gives ingen forberedelsestid. Eksaminationen indledes med elevens fremlæggelse af udvalgte dele af sin portfolio jf. pkt. 3.2, og former sig derefter som en uddybende samtale mellem eleven og eksaminatorerne. I den uddybende samtale kan øvrige dele af portfolien inddrages. Fremlæggelsen omfatter højst fem minutter af eksaminationstiden.

Bedømmelsen er en vurdering af, i hvor høj grad elevens mundtlige præstation lever op til de faglige mål, som de er angivet i pkt. 2.1.

Der gives én karakter ud fra en helhedsvurdering.

Appendix B: Formal description of the Advanced Methods of teaching science course

Københavns Universitet - Kurser

NNDK15002U Geografiens Didaktik

Årgang 2017/2018

Fold alle ud

Engelsk titel

Advanced Course in Teaching for Geography

Uddannelse

MSc Programme in Geography and Geoinformatics with a Minor Subject

Kursusindhold

I kurset arbejder vi med Geografi-didaktik, primært med gymnasiet som fokus.

- Læringsteori: Kontruktivisme med speciel fokus på undersøgelsesbaseret undervisning (inquiry)
- Læringsmål og målbeskrivelser
- Feltarbejde og eksperimentel arbejde
- Forståelsesproblemer i geografi
- Differentieret undervisning
- Undervisningssamarbejde der går udover traditionelle fagrammer

Målbeskrivelser

Viden om:
Læringsteori og didaktisk teori relevant for naturvidenskabelig undervisning i gymnasiet som angivet under undervisningsmaterialer.

Færdigheder:
Den studerende skal kunne ved kursets afslutning kunne:

- Planlægge og gennemføre inquiry-baseret undervisning
- Analysere og vurdere planlagte lektioner og lektionsforløb
- Tilrettelægge og organisere eksperimentelt arbejde samt feltarbejde i geografi
- Udarbejde og anvende målbeskrivelser til undervisningsplanlægning og gennemførelse
- Tilrettelægge undervisningsaktiviteter i samarbejde med lærere fra andre naturvidenskabelige fag og med ikke-gymnasiale institutioner
- Analysere og afhjælpe elevers forståelsesproblemer i geografi (alternative conceptions)

Kompetencer:
Den studerende skal ved kursets afslutning kunne planlægge, gennemføre, evaluere og reflektere over egen (og andres) naturvidenskabelige undervisning på gymnasieniveau ud fra udvalgte teoretiske betragtninger og argumenter.

Appendix C: Call for participants

Kære naturfags-undervisere

Jeg skriver til jer da jeg i øjeblikket er i gang med at skrive speciale i Naturfagsdidaktik ved Københavns Universitet.
I den forbindelse har jeg brug for hjælp fra jer der har haft et af kurserne: Videregående Naturfagsdidaktik, Geografiens didaktik, Naturfagsdidaktik for fysik eller Naturfagsdidaktik for biologi.

Jeg har selv taget kurset i Geografiens didaktik og synes det kunne være spændende at finde ud af, hvordan det vi har lært på kurset kan anvendes ude i undervisningen.
Kunne du være interesseret i at medvirke?

Det overordnede mål med mit projekt er at undersøge, hvordan gymnasielærere og andre der underviser benytter sig af og oplever undersøgelsesbaseret undervisning (Inquiry based teaching) i deres egne timer. Og i forlængelse af dette, hvilke udfordringer I oplever i forbindelse med implementeringen af undersøgelsesbaseret undervisning.

Jeg vil rigtig gerne lave et interview af ca. 30 minutters varighed, og hvis det er muligt observere noget undervisning som gerne må være (men ikke nødvendigvis) baseret på den undersøgelsesbaserede tilgang.

Såfremt du ønsker at deltage, vil du optræde anonymt i specialerapporten som du selvfølgelig vil få tilsendt så du kan læse, hvad der kommer ud af projektet, hvis du har lyst. Mine vejledere er Bob Evans og Lene Møller Madsen. De får ikke adgang til, hvem af jer jeg bruger som informanter, men udelukkende til information om hvilke fag der undervises i og hvilken årgang I kommer fra. Men de er selvfølgelig virkelig interesserede i at høre hvordan det går derude med jer i undervisningen.

Der kan ikke tilbydes økonomisk dispensation for deltagelse i projektet, så jeg appellerer primært til jeres lyst til at forbedre den didaktiske undervisning som SCIENCE tilbyder kommende gymnasielærere og undervisere.

Kontakt mig endelig hvis i har spørgsmålet til projektet.

I bedes svare hurtigst muligt, da jeg skal sikre mig at jeg har nok medvirkende - jeg sætter i denne forbindelse også pris på et nej tak, så jeg ved at jeg skal søge videre.

På forhånd tak for din tid.

Med venlig hilsen

Jakob Rasmus Holm

Appendix D: Interviewguide

Interviewguide: Briefing		
Præsentation	Hvem er jeg:	Mit navn er Jakob Holm. Jeg har læst Geografi med Historie som sidefag på Københavns universitet, og er nu i gang med at skrive speciale på Institut for naturfagenes didaktik
	Formålet med interviewet:	Formålet med interviewet er helt overordnet at høre om din undervisning og dine oplevelser med Inquiry-based teaching, positive som negative.
Rammer:	Tidsramme:	Interviewet kommer ca. Til at vare 30 min.
	Elektronik:	Interviewet optages på diktafon. Optagelsen vil fungere som støtte til min hukommelse og vil indgå i mit projekt.
	Anonymisering:	Interviewet vil selvfølgelig blive behandlet fortroligt. Og i projektet vil dit navn blive anonymiseret så dine udsagn ikke kan spores tilbage til dig.
	Spørgsmål og frivillighed:	Hvis der er noget du vil spørge om eller ikke forstår, skal du ikke holde dig tilbage. Det skal hertil siges at du jo deltager frivilligt i interviewet, så hvis der er noget du ikke

		ønsker at svare på, vil dette blive imødekommet
Præsentation af informanten:	Informanten præsenterer sig selv.	Navn, alder, undervisningserfaring, didaktisk erfaring, fag, klassetrin. Hvornår havde du et af de didaktiske kurser?

Forskningsspørgsmål	Interviewspørgsmål
En normal undervisningslektion:	- Hvordan bygger du normalt din undervisning op? - - Hvordan motiverer du dine elever? - - Har du en rød tråd i din undervisning? - - Hvor meget fylder de officielle læreplaner i din planlægning af dine timer? - - Hvor finder du inspiration til dine lektioner?
Læreres implementering af IBSE:	Inquiry-based teaching eller undersøgelsesbaseret undervisning er blevet formuleret på mange måder. - Vil du forsøge at definere det for mig? - Hvad er elevens rolle? - Hvad er lærerens rolle? IBSE-forløb kan variere lige fra enkeltlektioner til månedlange forløb. - Hvor ofte vil du mene at du benytter dig af Inquiry-undervisning? - Aldrig, sjældent, ugentligt, månedligt. - Foretrækker du korte eller lange forløb?

Fordele og udfordringer ved ISBE	- Hvorfor Inquiry-undervisning ses ofte som cyklusser eller modeller som 6F-modellen der er delt op i forskellige faser: Forudsæt Fang, forsk, forklar, forlæng, feedback. - Benytter du dig af 6F-modellen? - - Kan du finde på at benytte dig af enkelte af modellens faser og dermed lave en form for afbrudt inquiry-forløb? - - Hvilke faser benytter du flittigst/synes du det er mest oplagt at benytte i din undervisning? - - Hvor finder du inspiration til dine inquiry-lektioner? - Hvordan er din holdning til Inquiry? - Bruger du ofte apps i dine timer? - - - Hvordan er din arbejdsplads og kollegers holdning til IBSE? - Hvad kan ISBE tilføje til din undervisning som mere traditionel tavlestyret undervisning ikke kan? - - - Hvordan tager dine studerende imod inquiry? - Bliver de motiverede? - Kan de se ideen med det? - Hvilke udfordringer oplever du i forhold til at afholde inquiry-relaterede timer? - Materialer, tid, osv? - - Føler du at det er lettere at lave inquiry i et fag end i et andet?

	- Føler du at du kan benytte nogle af de ting du fik med fra didaktik-faget? Hvis ja, hvad?

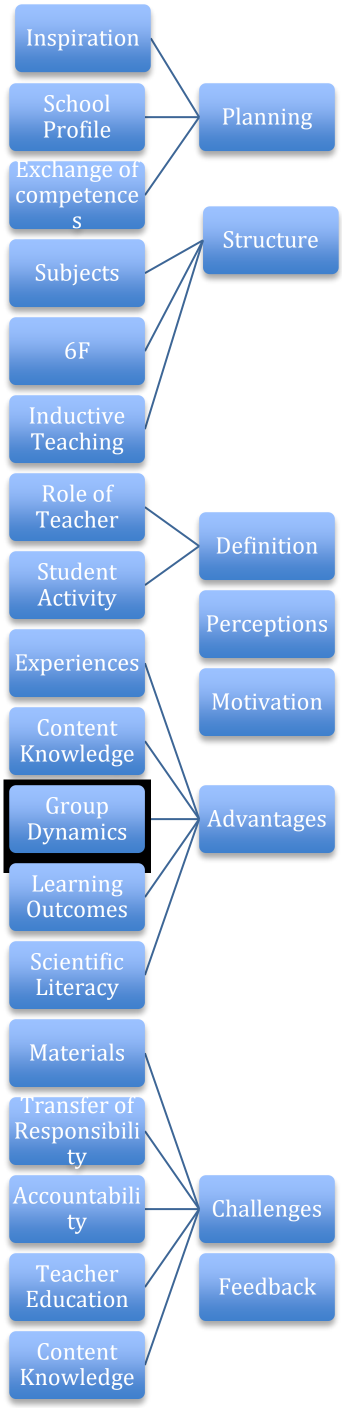
Appendix E: Classroom Observations

			Observation af undervisning				2018	Mick
Interval	0-10 min	10-20 min	20-30 min	30-35 min	35-40 min	40-45 min	60-85 min	85-90 min
Aktivitet	Kort præsentation og Løsning af hjemmelavede tests	Validering af tests. Den elev som har lavet testen retter den	Eleverne diskuterer deres resultater	I plenum opsummeres eksempler på hvad der er et godt spørgsmål.	Nyt emne bliver præsenteret. Motion og kost.	Præsentation af dagens emne.	Eleverne skal lave forskellige øvelser og måle deres puls	Opsamling og lektie til næste uge
Fase	Forlæng [1]	Forlæng	Forlæng		Fang	Fang/præsentation.	Forsk	
Elev Engagement	Højt. Det virker som om eleverne er engagerede af at de selv har lavet testen	Højt	I takt med at eleverne bliver færdige, falder engagementet lidt	Eleverne var overordnet enige i at det var en god måde at gribe det an på.	Højt. Eleverne kan relatere til det spørgsmål der er blevet stillet	Hører efter	Højt!	
Lærers rolle	Igangsætter undervisning og deler elever op i par	Går rundt og støtter og	Sørger for at alt forløber gnidningsfrit	Samler op på aktiviteten	Igangsætter ny aktivitet. Leder snakken til dopamin.	Taler	Går rundt og hjælper med praktiske spørgsmål.	
Arbejdsform	Eleverne har som lektie forberedt en test, som de så skal give hinanden. Dette tjener formålet at teste viden men har også metodisk værdi, da eleverne lærer noget om, hvad der er et godt spørgsmål	Langt hen ad vejen individuelt. Men nogle steder gruppeorienteret.	Eleverne diskuterer deres resultater af testene.	Plenum. Der diskuteres karakteristika af gode og dårlige spørgsmål.	Eleverne snakker med sidemakker om, hvad der er hårde aktiviteter. Der er lidt problemer med at finde ud af, hvor mange timer det drejer sig om.	Undervisning i plenum.	Eleverne arbejder i par. Ved hjælp af apps skal pulsen måles. Der var lidt forvirring om man skulle tage pulsen samtidig med at man tog pulsen eller om man skulle tage pulsen når man var færdig.	

				Observation af undervisning	d. 20/3 2018	Kemi C	10-11:50	Charl ie
Interval	0-15 min	15-25 min	25-30 min	30- 60 min	60- 70min	70- 110 min	- min	- min
Aktivitet	Præsentation af dagens emne som er filtrering af syre og base. Hvor meget ethansyre er der i husholdningseddike? Og vendespil.	Gennemgang af spørgsmål vedr. Eksamen, pensum og tekniske ting på Lectio	Dagens forsøg. Starter med 1 min. Summen om Hvad et ækvivalenspunkt er.	Eleverne udarbejder et forsøg hvor de skal beregne ækvivalenspunktet. Med indikatorvæske. phinolphtelein.	Pause	Journalarbejde. Eleverne udregner ækvivalenspunktet		
Fase	Fang	-	forudsæt	Forsk, men stilladseret	-	Stilladseret forsk		
Elev Engagement	3. Semi højt	4.	3. Hører efter	4. Højt	-	3. Svært at definere		
Lærers rolle	Faciliterer	Forklarer	Forklarer	faciliteter	-	Faciliterer og forklarer		
Arbejdsform	Eleverne spiller et vendespil som handler om at de skal memorere kemiske remedier	Eleverne stiller spørgsmål. Og er meget bekymrede om lockout	Eleverne hører efter og stiller spørgsmål om metoden	Eleverne forsker. Men der er en snært af kogebog.	-	Udregner og bruger det udleverede hjælpeark		

06/04 2018				Observation af undervisning	Elisabeth	1.x Roskilde Gymnasium
Interval	0-30 min (10:00-10:30)	5 min 10:30-10:35	10 min 10:35-10:45	15 min 10:45-11:00	20 min 11:00-11:20	10 min 11:20-11:30
Aktivitet	Eleverne har en halv time til at færdiggøre deres rapport om bølgelængden af lys. Et emne de har studeret i 3 moduler.	Pause	Det elektromagnetiske spektrum + lille film. Der bliver lavet en oversigt over bølgelængder Film med Kvantekarina	Fokus på UV Eleverne snakke sammen i par om UV. Der bliver samlet op på aktiviteten i plenum. Typer, positive og negative ting Snakker sammen to og to om, hvordan solcreme virker. Kort film om solcreme. *"How the sun sees you"*	Fokus på IR Ida har medbragt 3 kameraer som kan opfatte IR/varmestråling. Eleverne sendes rundt i grupper med et kamera og benytter kameraet. De laver på eget initiativ små forsøg, hvor de løber på trappen for at blive varmere, måler solen og andre ting.	Afrunding . opsamling på hvad eleverne har lært. Næste uges lektie bliver præsenteret.
Fase	Forklar	-	Forlæng,	forudsæt	Fang og forsk	forklar
Elev Engagement	4. Eleverne arbejder ud fra deres tidligere forsøg, og er derfor umiddelbart godt inde i opgaven.	-	5. Umiddelbart ganske godt. Der er mange der svarer og deltager.	4. Højt.	5. Meget højt. Det ville også være rigtig godt til en fang fase. (Teachable moment)	5. Klar til at pakke sammen.
Lærers rolle	Vejleder og guider	-	Spørger	Holder diskussionen i gang med ledende spørgsmål	Lader eleverne undersøge kameraerne på egen hånd	
Arbejdsform	Gruppearbejde. Hvor eleverne i fællesskab arbejder med at færdiggøre en rapport.	-	Klassediskussion Eleverne svarer på spørgsmål fra Ida vedr. Deres lektie. Hvad er det elektromagnetiske spektrum? Hvad kan vi generelt sige om ES? =Lys og bølger	Først i par og så i plenum.	Eleverne går i grupper ud på skolen og tager billeder med kameraerne. Der bliver opsamlet på på nogle af billederne og snakket om hvad man kunne udrede fra dem.	

Appendix F: The process of Coding



Appendix G: Excerpts from Elisabeth's STARWARS-themed unit.

Teori II: Brug af gitterligningen

Chewbacca sender laserlys fra sin bow caster (på dansk: laser armbrøst) gennem et optisk gitter og måler en afbøjningsvinkel på 12º. Afstanden mellem ridserne i det optiske gitter er på 2100 nm.

3. Hvilken bølgelængde har lyset?

4. Hvilken farve svarer det til?

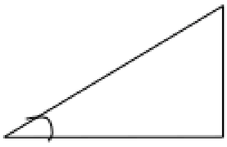
Han Solo bruger det samme gitter som Chewbacca og vil også gerne finde bølgelængden af lyset fra hans laser (højst sandsynligt en laser han har fundet). Desværre har han glemt sin vinkelmåler og må ikke låne Chewbaccas. Han måler i stedet to afstande.

- Afstanden fra gitteret til væggen hvor lyset rammer
- Afstanden mellem midterpletten og pletten som har den mindste afbøjningsvinkel (1. orden).

Det er nu hans opgave at finde afbøjningsvinklen (*φ)* ud fra disse to afstande.

Han Solo tænker på Yoda, som fortalte ham om retvinklede trekanter og hvor smart det er at bruge fx tangens, når man skal finde en vinkel og to af siderne.

$$\tan(\varphi) = \frac{\text{mod}}{hos}$$



eller $\varphi = \tan^{-1}(\frac{\text{mod}}{hos})$

5. Hjælp Han Solo med at finde afbøjningsvinkelen (*φ*) ud fra de to afstande, han har målt. Yoda siger vinkelen er 17,6° er det rigtigt?