From doing to learning

Inquiry- and context-based science education in primary school

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Biology

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Abstract

The aim of this thesis is to develop an understanding of primary school teachers' knowledge of Inquiry- and Context-Based Science Education (IC-BaSE) from different perspectives: what it is, how to use it and why these strategies are used. There are at least two reasons for performing research in this field. First, there is a need for professional development in teaching science among primary school teachers. Second, IC-BaSE has been suggested to provide useful instructional strategies for stimulating students' interests in learning science. The thesis contains four papers with the overall research question: How do primary school teachers reflect on Inquiry- and Context-based Science Education as a framework for teaching and learning in the primary school classroom? Both quantitative and qualitative research methods have been used. The main participants in the studies were twelve primary school teachers working with 10-12 year old students. The results are discussed with reference to theories mainly based on pragmatism, but also from a sociocultural perspective. Primary school teachers found IC-BaSE to provide useful instructional strategies in the primary school classroom, as it engaged their students and developed their skills in planning inquiries. The teachers developed their knowledge about IC-BaSE, what it is and how to use it. Furthermore, the primary purpose of using IC-BaSE seemed to be that students should have fun. Students also responded positive to the use of IC-BaSE. However when teachers were informed about their students' responses to IC-BaSE, they became more aware of the importance of informing the students about the purposes of the activities. The findings presented show that teachers need to move forward, not only be "doing", but also knowing *why* they are doing the activities and *how* to do them. Students' experiences can contribute to this awareness among teachers and develop the teaching practice.

Preface

This thesis focuses on Inquiry- and Context-Based Science Education (IC-BaSE) in primary school. One reason for carrying out this study is based on my experiences as a science teacher and personal beliefs in what constitutes good education. Another reason is my curiosity in finding out how teachers and students reflect on the ways to perform science education that I personally believe in. As a student in secondary school, I often experienced that inquiry-based lessons did not help me to understand the content, or the purpose of the inquiry. Later, during my years as a science teacher in secondary school, and as a teacher educator, it was important for me to teach science in a context, for reasons unknown to me at the time. Perhaps it was because I noticed that my students enjoyed working in this way, but it was not the only reason. It was also important for me that they could understand the content, and it seemed that my students were more motivated to learn if they could relate science to something in their lives. This is why it was, and still is, important for me that my students are aware of the purpose of every lesson activity and are motivated when doing the activities.

Inquiry-based teaching has changed from the time when I was a student until today. In those days, I believe that the purpose was mainly to confirm different science laws or concepts. Today, the purpose is rather that students should learn how to perform systematic inquiries and understand how scientists work and how scientific knowledge is developed. Using inquiry to confirm and visualise science concepts and laws is also a strategy used by teachers, especially in secondary school. The notion of context in the sense of connecting the content to be learned to everyday life is not anything I can remember at all from my time as a student.

Inquiry- or context-based teaching methods are instructional strategies that can be used by teachers for more reasons than just confirming facts or stimulating students' interest in learning science. However, these strategies are not always the best methods for helping students to understand science. Quite often, I have used drama to visualise and make science concepts easier for students to grasp. I believe that a teacher needs to have a range of instructional strategies to support students in their learning.

However, inquiry-based teaching is very much on the agenda in curricula all over the world, and organisations such as the European Commission stated some years ago that this is the way forward in science teaching (EC, 2007). Research has also shown that using context instead of teaching science as isolated facts is of importance to get students interested in science education. Since context, as mentioned, is also important to me, the use of context-based teaching combined with inquiry was of particular interest in my research.

As a teacher educator for many years, I have run courses with both pre- and in-service primary school teachers. I have always appreciated working with this category of teachers, finding them to be positive, open to different instructional strategies, curious and eager to learn science. When I was about to start my studies as a PhD student, I also found that most of my colleagues were doing research related to secondary school. I saw a need for more research in primary school. Only a few years ago (2011), a new curriculum for compulsory school in Sweden was implemented, and there is now a greater emphasis on science in primary school compared to the earlier curricula. The fact that many primary school teachers lack science in their teacher training education, or only have a limited number of courses, was another reason for me to focus on primary school.

So, here I am, with a thesis dealing with IC-BaSE in primary school, with the exception of Paper IV, which is a study of IC-BaSE as reflected on by secondary school students. Primary school students will eventually become secondary school students, and it might be of interest to find out how secondary school students respond to IC-BaSE. If this proves to be successful, it would be a further argument for preparing primary school students for these strategies. In my experience, and as shown in my studies and other research, these instructional strategies have proven to be successful for both primary and secondary school students. (By successful, I mean shown to stimulate students' learning in science). The main focus in this thesis, however, is on the primary school teachers and their responses to IC-BaSE. The reason for choosing a teacher perspective is their need for professional development (PD) in teaching science and also a research interest in how teachers can develop their knowledge and skills.

Several parts of this thesis have a common basis in the works of John Dewey. The use of IC-BaSE and the need for reflection are aspects of my thesis that have been discussed by Dewey. In the beginning of the 1990s, I graduated as a teacher of biology and chemistry with qualifications to teach in secondary school. During my university studies, the dominant educational philosophy was the constructivist theory of Piaget. Starting my career as a teacher, I found that his ideas also influenced teaching and collegial discussions. A few years later, I started to work as a teacher educator. During this period, the issue of students' misconceptions was on the agenda. However, gradually, the debate, research and, as a consequence, teacher education programmes became more and more influenced by the ideas of Vygotsky and the sociocultural perspective.

Ideas from Dewey were on the agenda during my first years as a teacher educator when I taught courses in outdoor education. In this area, the expression "learning by doing" and his name were frequently mentioned in literature and collegial discussions. At this time, I did not study Dewey, but only embraced the "learning by doing" expression, seeing it was a useful idea for my teaching. Several years later, after reading his works, I realised that the expression "learning by doing" does not reflect the whole truth of Dewey's philosophy. As a matter of fact, in all of his many works the coinage is not commonly used, except in the work *Schools of Tomorrow*. Today, as a researcher in science education, I still find the works of Dewey useful and influential for school policy documents, curricula and recommendations on how science ought to be taught.

I know that Dewey also emphasised the importance of reflection. During my PhD studies I have reflected a great deal, not only on my own practice as a teacher, but also on what it is like to be a researcher. I wish that my research may inspire primary school teachers to reflect on their practice and to enhance their science teaching skills.

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Other persons, in addition to the supervisors, who have been of importance: Shu-Nu Chang Rundgren, without you I probably would not have become a PhD student. Thank you for inviting me to the PROFILES project and arranging everything from the start. Fellow researchers in the SMEER group, I thank you for your support during my studies. Anders Jidesjö and Berit Bongum, you supported me with constructive comments at seminars. Your guidance was important and useful to me. Ann-Britt Enochsson, I appreciate your good advice. Bodil Svendsen, we have had so many interesting conversations during this period, I do hope we can perform some research together in the future.

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List of papers

Paper I: Walan, S., & Mc Ewen, B. Primary science teachers' reflections on Inquiry- and Context-Based Science Teaching. *Research in Science Education*. (2016). DOI: 10.1007/s11165-015-9507-5

Paper II: Walan, S., Mc Ewen, B., & Gericke, N. (2015). Enhancing primary science: An exploration of teachers' own ideas of solutions to challenges in inquiry- and context-based teaching. *Education 3-13: International Journal of Primary, Elementary and Early Years Education, 1-12*.

Paper III: Walan, S., Nilsson, P., & Mc Ewen, B. Why inquiry? - Primary teachers' objectives in choosing inquiry- and context-based instructional strategies to stimulate students' science learning. Resubmitted to *Research in Science Education*.

Paper IV: Walan, S., & Chang Rundgren, S.-N. (2015). Student responses to a context- and inquiry-based three-step teaching model. *Teaching Science, 61*(2), 33-39.

Link between the papers

This doctoral thesis is a compilation thesis comprising an introductory chapter and four papers. The introductory chapter includes a section on theoretical perspectives and a section presenting the methods used. It also provides short presentations of the results of the papers. Finally, there is a section discussing the results as well as the research process and implications and suggesting ideas for future research. The papers are not listed in the their chronological order but in the order of logic, that is, how the studies are linked to each other. The links between the papers are presented below.

The first study was peformed during a Continuous Professional Development (CPD) programme with twelve primary teachers. In the course of the programme, the teachers' reflections on IC-BaSE were investigated. The CPD programme resulted in a great deal of data, and the issues discussed by the participating teachers also resulted in the second paper in which the practical challenges of IC-BaSE are in focus. The teachers presented their own ideas for solutions. This was of particular interest to me, knowing that the challenges of science teaching have often been presented, as opposed to solutions. Another result of the CPD programme was that it raised questions of how primary school teachers reflected on the purposes of science teaching. Why did they choose a certain instructional strategies, i.e. IC-BaSE? During the CPD programme, I expected the teachers to also discuss the reasons for using IC-BaSE in relation to students' understanding. However, their discussions about the reasons for using IC-BaSE were mainly related to students' interest. Therefore, a study in which teachers' reasons for choosing IC-BaSE was carried out and resulted in the third paper.

The first threee studies were conducted together with teachers, but the fourth study targeted secondary students. In Papers I, II and III, the teachers reported how IC-BaSE engaged their students at primary school level. Since these students eventually will be secondary school students it was of interest to study how they responded to IC-BaSE. However, the core of the thesis is primary school teachers and their development in teaching science, particularly in relation to IC-BaSE. I hope my studies can contribute with insights into how primary school teachers can develop their knowledge of IC-BaSE and stimulate future research in this field. Furthermore, I also want to emphasise that in all of the papers I have had fellow researchers, but I am the first author and have done the main part of the work.

The CPD programme used in Paper I and II was fully designed by me. Data collection was mainly conducted by me, with the exception of field notes, which also were written by the second author of Paper I. Data analysis and writing processes were performed together with the second author of papers I and II. In addition, the third author of Paper II participated in the writing process of that article. In paper III, I had the main responsibility for the research design. The major part of data collection I performed on my own, with the exception of one interview, which was held together with the third author. Data analysis and the writing process were supported by the second and third authors. Finally, in the work presented in paper IV, the theoretical framework and the data collection were my responsibility. Research design, data analysis and writing process were performed together with the second author. In the thesis, I sometimes discuss the works as being my own studies, but as explained above, others have also been involved.

List of abbreviations

CK: Content Knowledge (corresponding to SMK)
CoRe: Content Representations
CPD: Continuous Professional Development
IC-BaSE: Inquiry- and Context-Based Science Education
NTA: Naturvetenskap och Teknik för Alla (Science and Technology for All)
PCK: Pedagogical Content Knowledge
PD: Professional Development
PK: Pedagogical Knowledge
PL: Professional Learning
PROFILES: Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science
SMK: Subject Matter Knowledge (corresponding to CK)
TPD: Teacher Professional Development

Table of contents

INTRODUCTION

In the following sections, an account and synthesis of current and past research in the areas of interest for my studies are provided. The most important concepts that I have used are presented as well as the arguments for choosing my research questions and topic, or in other words, my identification of a necessary gap to fill in science education research. Theoretical perspectives of my research were based on ideas from mainly a pragmatic perspective, but to some extent also from a sociocultural perspective. Aspects from earlier research I have presented as four different zooms related to the studies presented in the papers. Each zoom has a different perspective on the overall research question, moving from the general, to more and more specific. The first zoom is primary school Teachers' Professional Development (TPD) in teaching science. The second is, Pedagogical Content Knowledge (PCK, which will be further described later on). The third zoom is from one part of PCK, namely instructional strategies. Furthermore, this zoom includes the use of IC-BaSE, and teachers' knowledge about these strategies. The fourth and final zooming in is on the purposes of choosing certain instructional strategies.

Background to the studies

The background of the thesis is based on changes in the Swedish curriculum, which have led to the need for PD among primary school teachers. The demands on primary school teachers have increased, both nationally in Sweden and internationally. According to researchers (e.g. Anderson, Bartholomew, & Moeed, 2009; Appleton, 1995, 2006; Hackling, Peers, & Prain, 2007; Nilsson, 2008a; Palmer, 2001; Riggs & Enochs, 1990; Yates & Goodrum, 1990), many teachers at this level lack science education, or only have little knowledge. The importance of science teaching in primary school has been discussed by e.g. Lindahl (2003) and Keeley (2009), and research on teaching science at this level is the major focus in my thesis.

In 2011, the Swedish curriculum for compulsory school was changed. In this curriculum, science at primary school level has a more extensive and clearer function compared to earlier curricula. The subjects of science (biology, chemistry and physics) are presented separately, and for each there are specific aims, core content and knowledge requirements listed. These changes in the curriculum have led to new demands on the teachers, as they need to know more science compared to before. Subject knowledge is important and having a range of teaching skills is essential in dealing with changes that occur in the educational system.

A second reason why I consider the aspects of this thesis important is that earlier research has shown a great drop in students' attitudes towards science already between the ages of 8–11 (Murphy & Beggs, 2003; Sokolowska et al., 2014). Furthermore, researchers have argued that there is a need for changes in teaching strategies, and IC-BaSE has been suggested (EC, 2007, Osborne & Dillon, 2008). Using IC-BaSE as instructional strategies has proven to be successful in stimulating students' interest in science learning (Bennett & Holman, 2002; Bulte, Westbroek, de Jong & Pilot, 2006; Chen & Cowie, 2013, Gutwil-Wise, 2001; Kennedy, 2013, Parchmann et al., 2006).

The use of IC-BaSE, in combination with the need for TPD (e.g. Shulman, 1986, 1987; Nilsson, 2008a, 2008b, 2014), and the special need for knowledge about instructional strategies among primary school teachers (e.g. Roth, 2014) were areas of special interest. I found this to be an interesting gap to fill, to investigate primary school teachers' PD when using IC-BaSE as an instructional strategy. Thus, the aim of my studies was to develop an understanding about primary school teachers' knowledge about IC-BaSE from different perspectives: what it is, how to use it and why these strategies are used. The overall research question was:

How do primary school teachers reflect on Inquiry- and Context-based Science Education as a framework for teaching and learning in the primary school classroom?

Theoretical perspectives

Since all four papers of my thesis have an emphasis on the empirical part of the research and the typical journal format is limited, less space has been given to the theoretical background. Thus, the links to theories of relevance to my work are presented below.

Philosophical perspectives

The theoretical foundation of this thesis is based on two philosophical perspectives, the pragmatic and the sociocultural. Pragmatism is a philosophy that emerged in the late 1800s. According to Cherryholmes (1992), the first implicit declaration of pragmatism was made in 1905 by Peirce. He stressed that it was important to clarify meanings of intellectual concepts by tracing their conceivable practical consequences. The word *pragma* is Greek and can be translated as action, or activity (Stensmo, 1994). Dewey developed these ideas from the perspective of education, but he often used the term instrumentalism instead of pragmatism, because he saw thinking as an instrument for action (Dewey, 1980). From his perspective, thinking and knowledge were tools to solve scientific and everyday problems. His definition of pragmatism is in line with the one set by Peirce:

> Pragmatism is the doctrine that reality possesses practical character. (Dewey, 1931, p. 31)

In later years, pragmatism has been discussed by e.g. Peters (2007) who emphasised pragmatism as a theoretical framework including both theory and practice. He stated that pragmatists see the world as a set of practical actions that are born from thinking. Theory and practice are linked together as two sides of the same coin.

The sociocultural perspective is rooted in pragmatism, which holds that knowledge is constructed in activities where people interact with each other (Greeno, Collins & Resnick, 1996). Sociocultural perspectives often refer to the work of Vygotsky developed in the 1930s. According to Hodson and Hodson (1998), Vygotsky argued that development begins at the social level where individuals interact with cultural tools like language. Beck and Kosnik (2006) argued that some key features of a social constructivist (or sociocultural) perspective are the following: learning is social, knowledge is experience-based and constructed by the learners, and all aspects of a person are connected. These aspects include societal and cultural beliefs. In respect to the focus of this thesis, Anderson' s (2007) argument that social constructivist learning is consistent with the characteristics of inquiry-based learning is higly relevant.

Since this thesis is about primary school teachers and how they develop their science teaching through reflections, it may be argued that this is a socialcultural perspective. The teachers are interacting with each other and their reflections are affected by their societal and cultural beliefs. However, Dewey also discussed the importance of reflection from a pragmatic perspective (1938/1998). Thus, the importance of reflection may be discussed from both perspectives.

The study of the primary school teachers' reflections in this thesis has a focus on the practical aspect, dealing with instructional strategies in the form of IC-BaSE. These strategies can be discussed from both perspectives as well. However, I have found several links between the pragmatic perspective and the use of IC-BaSE, not only about the strategies in themselves, but also in the reasons for using them.

Important aspects of relevance to my studies are the ideas of teaching based on experiences and content related to everyday life, as well as the purposes of teaching and the importance of reflection. In the following sections, these aspects will be presented from a pragmatic and a sociocultural perspective.

How to teach? – Teaching based on experiences, students' interests and content related to everyday life

Dewey (1938/1998) discussed the differences between traditional teaching and progressive teaching. According to him, traditional teaching is the transmission of knowledge from teacher to student, where the latter should follow the rules and adapt to adult standards. This is, in other words, a top-down approach to teaching. Dewey advocated what he called "progressive teaching", in which students are expected to be active learners, instead of passive receptors. He also thought that facts should not be taught isolated from context, but rather be used as current opportunities in teaching. Dewey also stated that it is necessary to abandon obsolete subject matter in favour of working with the type of practical problems students might encounter in society (Dewey, 1938/2004). This is something that we still can relate to, not least because of the national curricular requirements for physics instruction:

> Instruction should provide students with opportunities to use and develop the skills and tools to formulate their own and view others' arguments in contexts where knowledge of physics is relevant. Thus, students should be equipped to handle the practical, ethical and aesthetic choices, such as energy, technology, environment and society (Swedish National Agency for Education, 2011).

Furthermore, Dewey argued that the activities in school should be based on students' experiences from home. The Swedish curriculum emphasises the importance of basing teaching on students' own experiences (although not specified in terms of home):

> Through teaching, students are given the opportunity to ask questions about physical phenomena and contexts based on their own experiences and current events (Swedish National Agency for Education, 2011).

He was also clear in his opinion that one of the main problems of school teaching was its isolation from everyday life and society. The holistic view was indeed important to Dewey, who stated that we live in a world where everything is connected, and that education and everyday life cannot be separated from each other. What students learn at school must be useful outside of school, and the experiences they have in everyday life must be brought into school. Dewey was not the first pragmatist to discuss the importance of relating to everyday life. Peirce (1878/1992) stated that if we are to have a full understanding of a concept, we need to supplement familiarity with it in day-to-day encounters.

Dewey also stressed that the teacher must consider and pay attention to what students are interested in as these interests are possibilities for development. He did not mean that teaching should be based on the student interests only, but that knowing about their interests may help the teacher in choosing teaching strategies and the materials to use. In this respect, Dewey emphasised the importance of working with their interests and preferences, since these tend to wax and wane. Children, or students, differ in their interests and capacities, but it is worth identifying interests and basing instruction on them. In discussing the development of children, or students, he remarked:

> Keeping in mind these fourfold interests – the interest in conversation or communication; in inquiry, or finding out things; in making things, or construction; and artistic expression – we may say they are the natural resources, the uninvested capital, upon the exercise of which depends the active growth of the child (Dewey, 1899/1980, p. 30).

Vygotskij (1999) also claimed that teaching should be built on students' interests. He argued that it is a general psychological law that if our interest is to be awakened, something needs to catch our attention and include some elements of novelty; otherwise, there will be no results. Furthermore, Vygotsky believed that in order to create interest among students, it was necessary for it to not be a false interest. He was critical of the forms of instruction that do not challenge students' thinking. He was also critical of the kind of methods that captured students' attention only by using tricks (like anecdotes or experiments) unrelated to the content, or the problem to be solved.

Dewey advocated teaching grounded in the experiences of everyday life (1938/1998). He thought that learning must be rooted in the conditions of experience and arouse an active request for information and new ideas. This is also the idea underlying the inquiry- and context-based teaching. However, it should be noted that it is not only a matter of experiences. On the contrary, subjects, facts and information are important parts in the process. In order for experiences to be educative, they must lead to an expanding world of subject matter of facts and information.

> It is a sound educational principle that students should be introduced to scientific subject matter and be initiated into facts and laws through acquaintance with everyday social applications (Dewey, 1938/1998, p. 98).

Dewey argued for the scientific method in teaching, i.e. raising questions, making hypothesis, testing, observing and reflecting upon what happened as a way of developing in most subjects (Dewey, 1938/1998). He claimed that the scientific method is the only authentic means at our disposal if we are to understand the meaning of our everyday experience in the world. Maybe that is why the expression "learning by doing" has become the Dewey motto. He did not see inquiry only as a way of gaining knowledge, but also as a way of learning how to solve problems, including both means and ends. Inquiry, according to Dewey, is grounded in experience. He believed that connection with a situation is what initiates inquiry. Furthermore he argued that when constituents do not hang together, a sense of confusion becomes a problem. As a natural step, the scientific method is used to solve the problem. Dewey also said that knowledge is the outcome of controlled inquiry. The process of inquiry involves formulating a problem, hypothesising, analysing and evaluating.

Vygotskij (1999) was also of the opinion that it is important that students can solve problems and find answers to questions they have asked themselves. He claimed that the scientific method was important and that the most important ambition is to challenge students' thinking and provide them with tools for a scientific approach (Lindqvist, 1999). It could be argued that Vygotskij (1999) also emphasised the importance of experience in the form of practice. According to him, a dialectical approach in which theory and practice are synthesised is important. To separate theory from practice is pointless, and all knowledge isolated from a context is worthless. He was very critical of that form of teaching.

The dialectical approach is typical for a sociocultural perspective, where contradictions support each other. Likewise, in works by Dewey (1938/1998, 1980), there is also a balance between different perspectives. Students should be free, but teachers should set limits; the students' needs and interests should guide the learning process, but you should have a curriculum to follow. It is precisely the interaction between the opposites that creates the optimal development.

Why are we doing this? – Purposes of teaching

Another aspect of Dewey's ideas, which I would like to highlight as important to my research, is motivation, or purpose and meaning. He argued that when facts are taught isolated from a context, it is difficult to motivate learning. Many studies have shown that student interest and motivation in science education is low (e.g. Fitzgerald, Dawson & Hackling, 2013; Hofstein, Eilks & Bybee, 2011; Holbrook, 2003; Osborne & Dillon, 2008). When students do not know why they are doing an activity, it has no meaning; merely performing hands-on activities does not contribute to successful student development. When students do something for a real reason which in addition is expected to provide real results, this develops attention and judgment abilities (e.g. Bennett & Holman, 2002; Bulte et al., 2006; Chen & Cowie, 2013, Gutwil-Wise, 2001; Kennedy, 2013, Parchmann et al., 2006). Dewey discussed this as having *ends-in-view* (1938/2004). Having *ends-in-view* may guide students among accessible possibilities of action. Dewey was critical of disembodied and decontextualised ends. He claimed that it is inappropriate to isolate and sanctify ends as values in themselves. One reason for this is that if one desired outcome is picked out, the only thing in the students' mind will be the idealised end. This may lead to contingencies and unexpected consequences of actions not be taken into account. This means that for students to have *ends-in-view* understanding of why they are doing things, teachers must also be aware of the *ends-in-view* and the importance of context. When students have *ends-in-view*, they may see the meaning of the activity and can participate on the basis of their earlier experiences.

Dewey (1938/2004) observed that growth, or development, is a movement towards a fixed goal. He wanted students to remain eager for further education. Today, there is a popular saying that "lifelong learning" is the ideal, but Dewey warned that the teaching conducted in his time was likely to make people glad to be finished with schooling. In the comments made by different researchers in *Experience* *and Education,* there are some interesting examples and observations. Darling Hammond commented:

> Students' prior experiences, motivations and interests are crucial to learning. Therefore, effective teachers emphasize students' needs rather than delivering instruction (p. 159).

Darling-Hammond also cited a teacher as being inspired by the ideas from Dewey:

> First and foremost, I think about what will interest these students and what they are familiar with that I can compare this new idea to…I also think about what their abilities are and what types of materials are available, then which of them the students would be most capable of handling. I try to get some variety into a lesson, perhaps changing activities two or three times during the course of the lesson to help connect with their interests (In Comments added in Dewey, 1938/1998, p. 160).

From a sociocultural perspective, Vygotskij (1999) also advocated for the importance of education being interesting. When Lemke (2001) discussed science education from a sociocultural perspective, he argued that personal feelings, or individual intellectual excitement, no matter what theory, could easily tempt us back towards an individualistic view of learning. He claimed that even if we make it obvious that social interactions are an essential part of learning, it is necessary to articulate that feelings are artefacts of communities as well. I interpret this as interests may vary in different cultures, or even within cultures. Furthermore, Lemke (2001) also had similar arguments as Dewey (1938/1998), addressing modern arguments on life-long learning. He stated that:

> … having an exciting experience with science is valid and valuable in itself, but education must always be more than one great experience after another… educations are always works-in-progress. How do we promote and support longer-term intellectual and personal development in a curriculum of great experience? (Lemke, 2001, p. 310).

Lemke's answer to the question was in line with the ideas of Dewey:

> … the curriculum need to work more vigorously against the radical separation of school from the rest of the students' lives (Lemke, 2001, p. 310).

The idea that the purposes of education are more than academic exercises to increase general knowledge has also been argued from a pragmatic perspective in recent years. Ardalan (2008) stated that pragmatism answers the questions of why and what should be learnt, and what the students will use the learning for. Seltzer-Kelly (2008) argued that the ideas of pragmatism about the purposes of teaching are that the point is not to learn the subject *per se*, but to make students learn to use scientific methods, and think and act on their own initiative. An effect of this is that the requirements placed on the teacher in a pragmatic context are enormous, according to Seltzer-Kelly (2008). It is not sufficient to know the subject matter, to be able to focus on the individual growth is required too. Furthermore, it is also important to be able to teach in open situations, to solve problems with no fixed amount of variables and to adjust instructional strategies to the individual students and their environmental influences. This is tantamount to requiring good pedagogical skills.

The importance of reflection

Reflection was another important part in education in the ideas of Dewey. This was commented on in one of his works:

> If education was to mean anything at all, it had to involve a heightened reflectiveness with respect to lived experience, a more conscious and thoughtful way of being in the world (Greene, in Dewey 1938/1998, pp. 119-120).

It is not uncommon that Dewey's works have been interpreted as valuing action more than thought and practice instead of theory, but he saw them as interdependent. The value of either in isolation makes no sense. However, when acting upon an idea, we can discover whether the idea is adequate or not, and if we are able to improve it. Indeed, Dewey put emphasis on thinking, planning, reflecting, interpreting and evaluating, much more than only "learning by doing". Furthermore, Dewey described reflective thinking as a state of doubt and as an act of inquiring to find a way to solve the doubts (Dewey, 1938/1998). The connection to experiences was clear to Dewey who found the process of reflection to be an active one in which knowledge was based on experience. Another aspect of reflection discussed by Dewey (1938/1998) was that it demands a community and the diverse perspectives on practice that community brings. Diverse points of view can broaden rather than narrow the conversation.

To Vygotskij (1999), it was important that teaching should aim to promote thinking and in order to do so, it was necessary to create obstacles that challenge the students' thinking. Through reflection it would be possible for the students to have a context for their learning. He also argued that when communicating with others, we could find new perspectives on ourselves. Accordingly, we could learn to reflect on our actions.

When Dewey and Vygotskij discussed the role of reflection, it was related to the education of children; however, in my research the focus is on teachers, but I believe that the ideas of Dewey and Vygoksij are applicable to teachers as well. The connection to my research and aspects of reflection is mainly in the discussions on teachers' PD when discussing their teaching in science.

Summarising philosophical perspectives with relevance to my research

Since the sociocultural perspective derives from pragmatism (Greeno, Collins & Resnick, 1996), there are many similarities. However, the emphasis on teaching connected to everyday life is more explicit in the pragmatic perspective. Both Dewey and Vygotskij discussed the use of inquiry as an important tool, albeit from slightly different perspectives, and they both also argued for the importance of interest as motivation.

So, how to teach? The idea is to avoid isolating school from society and everyday life. When teachers use teaching strategies such as inquiry- and context-based science teaching, the starting point is to use contexts based on the experiences and interests that students have in their everyday lives.

Why do we do this? This question was only posed by pragmatists, as it is a typical pragmatic question. Using IC-BaSE as a teaching strategy means that students know why they are supposed to do a certain experiment; hence, they are more motivated to learn. Dewey presented a way to contribute to student motivation by supporting them with *ends-in-view*.

The importance of reflection in order to stimulate learning and PD can find support in both ideas from pragmatism and a sociocultural perspective. Research about the importance of reflection will also be presented in the section about TPD.

Theoretical framework

In this section, I explain concepts I use. The concepts are presented in relation to the four levels of zooming in on aspects of importance in my research: TPD, PCK, instructional strategies (IC-BaSE) and the purposes of choosing certain strategies. The four levels of zooming in are not equal in size in terms of the amount of research I have presented; yet, all four are of equal importance in my research.

First zoom - Teachers' professional development (TPD)

Teachers' professional development (TPD) is the topic of Papers I and II, which report on an investigation of primary school teachers' reflections on IC-BaSE during a continuous professional development (CPD) programme. Paper III also centres on TPD, but this time during the teachers practice in schools and was investigated unrelated to any CPD programme. When I use the notion of TPD, it refers to teachers' professional development in general and covers professional development during teacher education (pre-service) and CPD programmes (in-service), as well as in their practice.

A general perspective on TPD

Before discussing studies on TPD, I will present this from a general perspective. Viellegas-Reimers (2003) has provided a thorough review on literature about TPD from an international perspective. According to her, teacher development is the professional growth a teacher achieves as a result of gaining increased experience and examining his or her teaching systematically. This can take place in small or large-scale projects, usually in a particular context and related to the daily activities of teachers and learners. The most effective TPD activities seem to be through study groups, learning studies, through action research and the use of portfolios for reflection (e.g. Adamson & Walker, 2011; Nilsson, 2014; Wood & McQuarrie, 1999). Which model to use for TPD should be based on the teachers' needs and also take into account the teachers' cultural background. The most common models used are courses, seminars and workshops.

To achieve successful TPD, there are some important aspects to consider. The programmes must be grounded in knowledge about teaching, offer intellectual, social and emotional engagement and include new ideas, materials and interactions with colleagues. Furthermore, school management should provide sufficient time and support for TPD. In addition, teachers need time to reflect in order to develop, as emphasised in the review by Viellegas-Reimers (2003). A culture of support is needed, with openness and trust, sufficient time and opportunities for teachers to learn to teach content in a context. The contexts wherein teachers teach are usually varied, and they have a great impact on teachers, their work and their PD.

To summarise the review by Viellgas-Reimers (2003), TPD efforts must be based on teachers' needs, related to their daily work in their school culture, provide time and be systematically planned. Furthermore, they must show a variation in methods, models and techniques, be aligned with curriculum and occur in collaboration with others.

Desimone (2009) presented similar aspects of importance for effective TPD in her review. She claimed that there is a consensus of five core features. She argued that these can be expressed in different words, still with the same meaning. According to her the five core features of effective TPD are: *content focus, active learning, coherence, duration,* and *collective participation*. She argued that content focus might be the most influential feature and that teachers must have the opportunity for active learning during the TPD. Furthermore, coherence is about the extent to which teacher learning is consistent with teachers' knowledge and beliefs, as well as with reforms and policies. Desimone claimed that according to research literature TPD programmes need to include at least 20 hours of contact with the teachers participating. Finally, collective participation of teachers from the same school, grade or departments can make interactions and discourse very powerful.

CPD programmes are systematic efforts to bring about change in classroom practice, in teachers' attitudes and beliefs and, as a consequence, also in students' learning outcomes. The reason for many teachers participating in development programmes is that they believe it will expand their knowledge and skills and contribute to more effectiveness in teaching (Guskey, 2002). Teachers also hope they will have concrete and practical ideas that directly relate to their day-to-day situations in their classrooms (Fullan & Miles, 1992). Guskey (2002) reported that the experience of successful implementations is what really changes teachers, not only attending teaching programmes. Teachers believe things work when they see them work in the classroom (Guskey, 2002). Borko (2004) and Schneider and Plasman (2011) claimed that the most powerful teaching and learning experiences are based on investigations in teachers' own classrooms. Another aspect of TPD is that successful results are found when development efforts are made together with teachers instead of being designed as doing things to teachers (e.g. Clarke & Hollingsworth, 2002; Nilsson, 2014). In other words, there is a shift from teachers being passive participants to becoming active learners.

Rauch (2010) has discussed how to ensure an effective CPD. Important factors include the programme not being of short duration, giving opportunities for in-depth discussions of contents and demonstrating a variety of methodological settings. Furthermore, CPD programmes should connect with the participants' classroom practices, have subject-specific methodological focus on selected issues and give opportunity for systematic reflection on the teacher's own practice. Rauch (2010) also recommended that CPD programmes should provide support for cooperation among teachers through networks beyond the CPD workshop/course.

Borko (2004) discussed what is known about PD programmes and their impact on teacher learning. She came to the conclusion that teachers' knowledge and practices indeed can change through PD programmes. Borko (2004) also argued that strong professional communities can foster teacher learning and instructional improvement, attributes often found in CPD programmes. As argued above by Rauch (2010), the experiences of classroom practices are powerful tools for facilitating teacher change. However, it has also been stressed that the PD activities need to actually occur in the classrooms, but records of classrooms activities like video-recordings, instructional plans and assignments may be used as well. Such records can enable teachers to examine their instructional strategies and student learning, and allow them opportunities to discuss ideas on how to improve their teaching (Little, Gearhart, Curry, & Kafka, 2003).

The importance of reflection in TPD

In a study of PD of science teachers, Harrison, Hofstein, Eylon and Simon (2008) declared that effective CPD needs to provide opportunity for teacher reflection based on classroom practice. Besides video recordings, interviews and observations, portfolios written by the teachers were used as research tools in their study. As shown in previous research, portfolios are a positive factor in enhancing learning and development (e.g. Dinhman & Scott, 2003). Harrison and colleagues (2008) stressed that learning through reflection is the central idea in use of portfolios.

In another study, conducted by Taitelbaum, Mamlok-Naaman, Carmelie and Hofstein (2008), the same kind of tools were used for collecting evidence on teachers' development during a CPD programme. The focus of the study by Taitelbaum and colleagues (2008) was on teachers' development in how to use the inquiry approach in the chemistry laboratory. The CPD programme resulted in teachers becoming more reflective and aware of their practice. They gained pedagogical and content knowledge through inquiry teaching. Teachers also developed teaching strategies in leading and tutoring students who worked in small collaborative groups. Data and analysis showed that teachers' dialogue with students became more meaningful and lengthy at the end of the CPD programme.

Providing time for reflection on teaching practice seems to be a key factor for teacher development. This has been stressed by several researchers (e.g. Harrison et al., 2008; Nilsson, 2009; Schneider & Plasman, 2011; Schön, 1983). Importance of reflection in TPD has also been discussed by, for instance, Simoncini, Lasen and Rocco (2014) and Prestridge (2014). When teachers become aware of their practice, there is opportunity for change. The key is awareness. This was also stressed by Rauch (2010), who claims that strengthening professional self-awareness is a major concern in teacher development processes. Conveying methods for systematic reflection on one's own work is, according to Rauch (2010), a core element. In addition, Lin, Hong, Yang and Lee (2013) have presented how primary school teachers' reflection on inquiry teaching developed when they discussed together with each other and researchers. Student responses to teaching also affected their inquiry teaching development. Lin and colleagues (2013) concluded that collaborative reflections acted as a facilitating agent for the primary school teachers' PD and student responses and researchers' comments acted as a catalytic agent. In Paper III, I presented how student responses in particular have impact on teachers' reflections.

Professional learning versus professional development

I have often encountered instances when teachers' professional learning (PL) and PD were used together. Still, is there a difference between them and if so, how are they related? In order to deal with this issue, some definitions of PL and PD are necessary.

Borko (2004) referred to PL as a situated agency, not as something being done to teachers, but as a process of development of their capacity to interpret particular situations and change their actions accordingly.

Bell and Gilbert (1996) used both PL and PD and regarded different phases of PD as part of PL. They argued that PD consisted of various phases: personal, social and professional. The personal phase dealt with individuals' thoughts and feelings, the social phase concerned collaboration and finally, the professional phase was conceptualised as changes in classroom practice. They explained the process of gaining PL as the following phases. First, a teacher finds some parts of his or her own teaching practice to be somehow problematic (personal development). Second, the teacher develops a willingness to discuss the problem with others (social development). Finally, the teacher takes the role as learner and tries out new activities in the classroom (PD).

Thus, PD is strongly connected to classroom practice, as has been argued by several researchers (Borko, 2004; Fullan & Miles, 1992; Guskey, 2002; Rauch, 2010; Schneider & Plasman, 2011; Viellegas-

Reimers, 2003) as well as by Desimone (2009), Feinamn-Nemser (2001) and Roth (2007).

The definition provided by Viellegas-Reimers (2003) based on her review on TPD referred to PD as professional growth from experience and examination (reflection) on teachers' own teaching. Timperley (2008) discussed PL as strongly shaped by practice and teachers' experiences.

During the last few years, researchers have claimed that the notion PD indicates a process by which something is done to and for teachers, while PL entails work with and by teachers (e.g. Hargreaves & Fullan, 2012; Nilsson, 2014; Nilsson & Loughran, 2012). These latest arguments could be used to claim that my research, instead of having TPD as my first zoom, should actually be teachers' professional learning.

Summarising aspects of TPD

TPD is essential to improve teaching, as educational reforms around the world constantly demand teachers to have more knowledge and competencies (Borko, 2004). Furthermore, it is important that TPD is seen as continuum from pre-service education level to in-service teachers' professional learning and development (Feinam-Nemser, 2001, Hiebert, Morris, Berk, & Jansen, 2007). Researchers have also identified several factors of importance if CPD programmes will have any sustainable effect on teachers. In summary, the factors of importance for TPD are the following:

- Connection to school practice
- Length of the CPD programme
- Time for reflection
- Based on teachers' needs and the context and culture they come from
- The CPD being performed together with teachers, not aiming to do something to them
- Variation in methods
- Providing support for cooperation during and after the CPD

Second zoom - Teachers' Pedagogical Content Knowledge (PCK)

So far, I have presented the first zooming in on my studies, TPD. The second zoom, Pedagogical Content Knowledge (PCK) is a dimension of PCK that teachers need to develop. Studies in which science teachers have expressed their needs (e.g. Alake-Tuenter et al., 2012; Appleton, 2006; Käpylä, Heikkinen and Asunta, 2009; Nilsson, 2008a, 2009) have revealed that teachers feel a lack of Subject Matter Knowledge (SMK), and therefore lack confidence in teaching. Another need, mentioned by both pre-service and in-service teachers, is to develop their knowledge about different instructional strategies to support students' learning (e.g. Alake-Tuenter et al., 2012; Käpylä et al., 2009; Nilsson, 2009, 2014). Nilsson (2009) found in her study that teachers expressed a need to know how to be more self-reflective and also how to be able to relate scientific concepts to everyday situations to stimulate students' understanding. Appleton (2007) argued that there is a need for both SMK and PCK among primary school teachers. However, PCK was of major interest in my studies. This section includes short presentation of some aspects of teachers' knowledge, with the main focus on PCK.

Basic forms of professional knowledge

Some forms of professional knowledge have already been mentioned. There seems to be three kinds of basic knowledge: general pedagogical knowledge, or simply Pedagogical Knowledge (PK), SMK, sometimes also called content knowledge (CK) and PCK. These types were introduced by Shulman (1986, 1987).

PK includes knowledge of learning environments, classroom management and learning processes, in general, but not in relation to a specific subject. SMK involves knowledge of a discipline, and when discussed in relation to primary school teachers and science, it is often presented as a problem because primary school teachers lack this kind of knowledge, as mentioned above. When Shulman (1986, 1987) presented his categories of teachers' knowledge, he divided SMK into substantive and syntactic. The first relates to the organisation of concepts, facts, theories, etc., of the subject. The second is the evidence and proofs used to generate the knowledge.

PCK covers aspects of how to teach a subject, knowledge of strategies and representations, of curriculum, materials, students' understanding and misconceptions. Viellegas-Reimers (2003) also listed other kinds of aspects important for teachers to know, such as student contexts, having a repertoire of metaphors to be able to bridge theory and practice, knowing how to use technology in teaching and how to support students from different cultural and social backgrounds.

Recently, a new model of teachers' knowledge and skills was presented (Gess-Newsome, 2015). The model includes PCK, but also several other aspects such as teachers' and students' beliefs, classroom context, student outcomes, etcetera. Hence, future research relating to PCK will probably be discussed in terms of this model. For my studies the model of Magnusson, Krajcik and Borko (1999) served as a foundation for discussing PCK.

The concept PCK

Magnusson et al. (1999) have argued that PCK is determined by the content to be taught, thus, SMK influences PCK. This has also been supported by other researchers (e.g. Appleton, 2006; Halim & Meerah, 2002; Hasweh, 1987; Käpylä et al., 2009; Nilsson, 2008a, 2009; Van Driel, Verloop, & de Vos, 1998). Baxter and Lederman (1999) argued that PCK is constituted by what a teacher knows, what a teacher does and the reasons for a teacher's actions. The reasons for teachers' actions were of particular interest in Paper III.

Research on PCK has grown since Shulman first presented the notion in the 1980s, and it has been discussed, developed and used by several researchers (e.g. Gess-Newsome, 1999; Grossman, 1990; Kind, 2009; Nilsson, 2014). However, the model of Magnusson et al. (1999) has been frequently used by, for example Park and Chen (2012) and Nilsson (2014). Moreover, the model was used in my first paper to elucidate teachers' reflections on inquiry- and context-based teaching. Magnusson et al. (1999) defined PCK as:

> Pedagogical content knowledge is a teachers' understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented and adapted to the diverse interests and abilities of learners, and then presented for instruction (p. 96).

Furthermore, Magnusson and colleagues (1999) divided PCK into the following components:

- Teachers' orientations towards science teaching (knowledge and beliefs about the purposes and goals of science teaching)
- Teachers' knowledge of instructional strategies
- Knowledge about science curriculum (goals and objectives relevant to the specific subject)
- Teachers' knowledge of students' understanding or any learning difficulties of specific science concepts
- Teachers' knowledge of assessment

Magnusson et al. (1999) argued that the above-mentioned components interact in complex ways and that teachers need to develop all five components of PCK. Even though the components interact, one of them was of particular interest in my studies, namely teachers' knowledge of instructional strategies, and even more specifically, inquiry- and context-based strategies.

PCK is included in the new model of teacher professional knowledge, as already mentioned (Gess-Newsome, 2015). However, in this model the view of PCK is much more complex compared to the model presented by Magnusson et al. (1999). Knowledge of instructional strategies is still included, but now classified as topic-specific professional knowledge.

How to capture PCK

In discussing how PCK has been investigated, Abell (2007) presented examples of studies, using classroom observations, interviews and group discussion analysis. She concluded that given the complexity of representing PCK, studies using multiple methods are the richest. In her review, Kind (2009) presented how researchers had used different approaches to capture teachers' PCK. She mentioned that this could be investigated through *in situ* studies, studying how teachers teach in the classroom, or performed by using probes like video excerpts or lesson transcripts. She also provided examples of intervention studies investigating changes in the responses from the teachers before and after the intervention. Kind (2009) explained that studies capturing

PCK could be collected during an extended period of time or captured in an instant. The former strategy of investigating during a longer period was the most commonly used.

Furthermore, Kind (2009) discussed methods for data collection, capturing PCK using rubrics to tabulate teachers' thinking about their work. One example was based on the use with pre-service teachers. The second rubric she presented was the one developed by Loughran, Mulhall and Berry (2004). They believed that it is important that teachers can articulate their practice in relation to knowledge and theories, which is of importance to better understand and evaluate scientific education. To this end, they have developed a tool to capture PCK in a holistic manner. The tool consists of two parts: Content Representation (CoRe), which has the function of representing what, how and why a certain topic is taught and Pedagogical experience repertoire (PaP-eR). These tools have been used to offer insights into the nature of PCK and to present a way in which issues of particular science content as well as strategies of how to teach can be captured (Loughran, Mulhall, & Berry, 2008).

The CoRe has been used in later studies (e.g. Nilsson & Loughran, 2012; Nilsson, 2013). In CoRe, aspects of students' difficulties in learning a particular content are covered, such as why the content is important to teach, ways of engaging students in the content as well as teaching strategies (Loughran, et al., 2008). In CoRe, there is a term called *Big idea,* which is not considered to be a pure fact from a textbook, but a general knowledge of an important phenomenon or concept. The first step of CoRe is to decide which big ideas are in focus when working with a particular topic. Kind (2009) found CoRe to be a useful tool for teachers to problematise their own knowledge about teaching a specific topic and a valid instrument in articulating PCK. This tool was used in Paper III to analyse primary school teachers' reflections when they used an inquiry- and context-based teaching model as part of their instructional strategies. There are even more methods used to capture or measure PCK for example, Science Teachers Learning from Lesson Analysis (STeLLA) using video-analysis (Roth et al., 2011) or from Borowski et al. (2012). In the latter, statistical analysis of data were used.

Teachers' development of PCK

Definitions of PCK have been presented above. However, when discussing teachers' development of PCK, the definition by Loughran, et al. (2006) is of interest. They argued that PCK is the knowledge teachers develop through experience of how to teach a specific content in such a way that it improves students' learning as well as their long-term knowledge retention. In other words, experience is an important factor and especially teachers' experiences of classrooms are important to describe PCK. Other researchers (e.g. Marks, 1991) have claimed that years of experience do not automatically lead to teachers developing PCK. Clermont, Borko and Krajcik (1994) have argued that experience of previous planning and teaching is related to development of PCK, but they also mentioned teachers' reflection as having an impact on PCK.

Researchers (e.g. Jones, Carter & Rua, 1999; Nilsson, 2008b) have described how PCK develops among pre-service teachers in primary school. In my studies, I was interested in in-service primary school teachers and their PCK. As Kind (2009) pointed out, a novice teacher is not "born" with PCK, and it takes time to acquire a bank of knowledge and skills to develop PCK. She stated that time is not enough; rather good SMK, good classroom experiences and a supporting atmosphere in the school context are also necessary. She emphasised the relation between PCK and SMK and argued that if good SMK is absent, it will affect teachers' choice of instructional strategies, moving from active to more passive strategies. With bad SMK, the teacher also shows less understanding of students' learning difficulties related to science.

Abell (2007) noting the descriptive nature of research on teacher knowledge, has called for research on teacher practice:

> The research in both SMK and PCK has predominantly been at the level of description. The ultimate goal of science teacher knowledge research must be not only to understand teachers' knowledge, but also to improve practice, thereby improving student learning (p. 1134).

Van Driel, Berry and Meirink (2014) have also argued that PCK studies so far have mainly documented the status quo. In the future, they call for studies that focus on the development of science teachers' PCK through the use of interventions, which is my intention in Papers I, II and III.

The study by Park and Oliver (2008) presented an overview of PCK and how this could serve as a conceptual tool to understand teachers as professionals. They argued that PCK covers both teachers' understanding and their actions. They added the importance of reflection to their model of PCK, both in-action and on-action, based on the studies by Schön (1983, 1987). Nilsson (2009) also claimed that reflection is important for teachers' development of PCK. When Magnusson and colleagues (1999) discussed teachers' development of PCK, they maintained that PCK is determined by the content to be taught, the context in which the teaching occurs, but also the way teachers reflect on their teaching experience. The importance of teachers' reflection has earlier been discussed in the section about TPD.

In their study, Park and Oliver (2008) found that students had important impact on the development of teachers' PCK from several aspects. The students had an influence on teachers' development of PCK through the questions they asked, their misconceptions and their engagement during lessons. This finding is considered in paper III. Nilsson (2009) found in her research that student teachers thought that lesson evaluations made by their students served as important tool in helping them to identify aspects of their own teaching. One of the aspects noted by the trainees was the importance of making science relevant to students. Furthermore, the students' experiences of the lessons made trainees aware of the parts of the lessons that were or were not in line with the purpose of their teaching.

In the new model of teachers' knowledge (Gess-Newsome, 2015), the role of students has been included. This was presented as a box of its own, titled *Student amplifiers and filters* (representing students' beliefs, prior knowledge and behaviours). There was also a box for *Student outcomes*. Both of these boxes are connected to PCK as they influence what occurs in the classroom (Gess-Newsome, 2015). She claimed that students' responses could have an effect on, for instance, the choice of instructional strategies. If a teacher meets resistance from the students, it may result in a decreased willingness to implement new instructional strategies.

The PCK component instructional strategies

Since this thesis focuses on aspects of inquiry- and context-based instructional strategies, this PCK component was of particular interest. Magnusson and colleagues (1999) divided instructional strategies into two groups: subject-specific and topic-specific strategies. The subject-specific strategies are those typical of teaching science, and the topic-specific ones apply to strategies being used to teach particular topics within a domain of science. When discussing subject-specific strategies, they mentioned teaching models using learning cycles in different phases or steps, such as *exploration, term introduction and concept application* as well as specific teaching models. In topic-specific strategies, certain representations or particular activities are used, according to Magnusson and colleagues (1999). The representations can, for example, be different models, illustrations or analogies. Activities can be problems, demonstrations and experiments. However, it is of interest to note that in the new model of teacher professional knowledge and skill, instructional strategies are considered to be topic-specific (Gess-Newsome, 2015). Without arguing about the division of instructional strategies into topic- or subject-specific, I will continue the discussion of instructional strategies from a general perspective.

Abell (2007) claimed that more research should examine what teachers understand about inquiry strategies and science teaching models, which was the focus of Papers I, II and III. Magnusson and colleagues (1999) also maintained that teachers' knowledge of strategies for teaching science is limited and that there is a need to develop this knowledge among primary school teachers (Roth, 2014). Teaching is, however, much more than having a range of good activities; there is a need for teachers to be familiar with, and capable of using different strategies, and not only from the perspective of the strategies as a goal in themselves (Loughran, Berry & Mulhall, 2012).

Summarising aspects of PCK

PCK is a complex construct, which was initially introduced by Shulman (1986, 1987). The model of PCK developed by Magnusson et al. (1999) served as a major foundation during my studies. This model included knowledge about instructional strategies, which was of particular interest to me. I have presented different researchers opinions on factors affecting teachers' development of PCK, such as experience, good SMK, support in the school context, teachers' reflection, etcetera. I have also mentioned how researchers have tried to cover just a single, or some part of PCK as well as integrate all components. Furthermore, I have discussed different methods of how to capture PCK, which have ended up in the model developed by Loughran, et al. (2004) using CoRe, which was a tool I used in Paper III. The section about PCK also included some discussion on students affecting teachers' PCK as presented by Park and Oliver (2008), and Gess-Newsome (2015). Finally, I concluded the section about PCK on the component instructional strategies. The focus was on the explanation of the component as provided by Magnusson et al. (1999), and I also mentioned how earlier research (e.g. Abell, 2007, Roth, 2014) have argued for the need of more knowledge of instructional strategies among primary school teachers.

Third zoom - Inquiry- and Context-Based Science Education (IC-BaSE) as instructional strategies

The third zooming in is on the particular PCK component, instructional strategies. The main reason for this zoom is the problem of students' low interest in science education and how earlier research has promoted IC-BaSE as part of the solution. In this section, I discuss some of this research as well as explain the concepts of inquiry- and context-based strategies.

Students' low interest in science education and IC-BaSE as part of the solution

In many developed countries, there is a problem with young people's low interest in science education (e.g. Fitzgerald, Dawson & Hackling, 2013; Hofstein, Eilks & Bybee, 2011; Holbrook, 2003; Osborne & Dillon, 2008). This has also been reported in international studies (i.e.

the ROSE project, Schreiner & Sjøberg, 2004). One reason mentioned quite frequently is that learners perceive science and science education as irrelevant both to themselves and to the society in which they live. As a result, science teachers are required to better motivate their students and interest them in science subjects (Holbrook, 2008; Newton 1988). Lyons (2006) found in his study (including students from Australia, Sweden and United Kingdom) that students encountered transmissive pedagogies in science teaching, and that the content was decontexualised. Lyons suggested that this could be a factor influencing students to perceive school science as a field difficult to understand.

Most of the studies of students' low interest in science education have focused on secondary students (Hargreaves & Galton, 2002). In her longitudinal study, Lindahl (2003) found that interest in science is mainly formed during the primary school period and the teachers' role is of great importance. Maltese and Tai (2010) came to the conclusion that additional efforts are needed in early grades to attract students to science and technology educations. Researchers, such as Osborne, Simon and Collins (2003) as well as Riegle-Crumb, Moore and Ramos-Wada (2010), have found that most young children have positive attitudes towards and are interested in learning science. Unfortunately, studies have also shown a great drop in students' attitudes towards science between the ages of 8–11 (Murphy & Beggs, 2003; Sokolowska et al., 2014.)

Maltese, Melki and Wiebke (2014) found that the most critical factors in generating interest in science and technology are lessons in school and that the teacher is the most important person in sparking initial interest. From these findings, it is easy to see the need for and importance of TPD (e.g. Nilsson, 2008a, 2014; Shulman, 1986, 1987). However, this is not the only solution presented. In addition, research has indicated that IC-BaSE could increase students' interests in learning sciences.

During the past few years, the European Commission has pointed out that there is a need for change in the teaching of science subjects and the focus must move towards IC-BaSE (EC, 2007). This was also noted by Osborne and Dillon (2008), and IC-BaSE has proved to be successful in stimulating students' interest in science learning (Bennett & Holman, 2002; Bulte et al., 2006; Chen & Cowie, 2013, Gutwil-Wise, 2001; Kennedy, 2013; Parchmann et al., 2006). Osborne, Simons and Collins (2003) observed that it was surprising that so little work has been done to identify the style of teaching and activities that engage students in the science classroom.

Fitzgerald et al. (2013), Krapp and Prenzel (2011), Potvin and Hasni (2014) as well as The Royal Society (2008) have pointed to the need for research that shows when teaching engages students in science and to highlight the "good news" stories. Tytler, Waldrip and Griffiths (2004) and Xu, Coats and Davidsson (2012) have shown that in science teaching teachers stress the need to link the content to students' lives. Fitzgerald and colleagues (2013) explored how primary schoolteachers create learning environments that stimulate interest, and in what way their teaching approach is a key factor contributing to student interest.

The concept of inquiry-based science education

What is meant with inquiry-based science education? Several studies discussing inquiry-based science education refer to the National Science Education Standards (NRC, 1996) or the Next Generation Science Standards (NGSS, 2013). In the latter, inquiry-based teaching is defined as a teaching strategy that involves engaging students in using critical thinking skills. The skills include asking questions, designing and carrying out investigations, interpreting data as evidence, creating arguments, building models and communicating findings. Using inquiry in this way should deepen students' understanding of using logic and evidence about the natural world.

As discussed by Crawford (2014), there are variations of inquiry, based on different notions such as project-based science, problem-based learning, authentic science, citizen science or model-based inquiry. In other words, there still seems to be some confusion about what inquiry really is (Wallace & Kang, 2004; Windschitl, 2004). Other researchers have explained that inquiry can be performed at different levels of openness. Types of inquiry-based teaching may vary from being confirming, structured or guided, to having an open approach (Banchi & Bell, 2008; Domin, 1999; Schwab, 1960; Windschitl, 2003). The confirmation level is when inquiry is performed to confirm a law or concept. Structured inquiry is when the teacher gives the question to be investigated and also the investigation technique. Furthermore, in guided inquiry, the teacher gives the question, but not the procedure of how to investigate. Finally, in open inquiry, the students both ask the question and plan how to investigate. In other words, levels of inquiry depend on the amount of student and teacher involvement in each of the parts of inquiry. There are also researchers (e.g. Magee & Flessner, 2012) who have claimed that closed inquiry is not really inquiry.

Inquiry-based instructional strategies in primary school

From my perspective, primary school teachers' use of inquiry in their teaching was of major interest. In Australia, a study investigated inquiry-based teaching approaches in primary school (Ireland, Watters, Lunn Brownlee, & Lupton, 2014). Different purposes of inquiry-based teaching were found, such as improving competences in students' problem-solving, focusing on the practice of scientific process skills, observing student-driven engagement, getting experiences by using students' senses, and noticing students having fun.

In another study by Lee, Hart, Cuevas and Enders (2004), it was investigated how primary school teachers developed their teaching in science using inquiry-based instructional strategies. One of the interesting findings was the teachers' reflections on the goals of science instruction. It was shown that they had three broad goal categories for their students in science: cognitive, affective and pragmatic. The cognitive goals included scientific method, critical thinking, problem solving, science understanding and applications of science in real-world situations. The affective goals were to stimulate the students in enjoying science. The pragmatic goals were to meet benchmarks, prepare students for assessments and integrate science across the curricular areas. One of the cognitive goals, of interest in the studies was the goal relating to the question *why*, that is, making students critical thinkers who ask questions and do not simply accept things stated in a book. However, they did not mention explicitly the question of asking *why* inquiries were made, which was of particular relevance in my third paper. I will discuss the purposes of teaching later on.

The study by Lee and colleagues (2004) unfortunately showed that despite participation in a development programme using inquiry, teachers did not improve their practice in instruction when content became more challenging. Another study investigating teachers' understanding of inquiry was performed by Wee, Shepardson, Fast and Harbor (2007). They showed that classroom implementation of inquiry did little to improve teachers' individual understanding of inquiry, even though they had attended a course about inquiry-based teaching. The conclusion drawn was that CPD programmes need to give more support to teachers during implementation (Wee et al., 2007).

In their review, Capps, Crawford and Constas (2012) referred to researchers who found that primary school teachers often have little, or no formal science training, and lack familiarity with the fundamentals of scientific inquiry. In another review by Roth (2014), the same conclusions were drawn. She mentioned that primary school teachers engage in hands-on activities without linking them to scientific ideas and practices. On the whole, few studies have examined inquiry-based science teaching in primary school classrooms (Harnik & Ross, 2004; Riggs & Kimbrough, 2002), and in general many primary school teachers have limited experience of inquiry-based science teaching (Leonard, Boakes, & Moore, 2009). Lee and colleagues (2004) suggested that primary school teachers lack knowledge of how science inquiry works and also how to implement inquiry-based teaching in the classrooms. Discussing a teacher competence profile for primary level inquiry-based teaching, Alake-Alake-Tuenter et al. (2014) observed that to teach in an inquiry-based way teachers need SMK and PCK, but found that their attitudes towards science and themselves as science teachers also influenced their competence. In their study, the different aspects of PCK are emphasised.

In yet another study (Abell & McDonald, 2006), it is described how primary school teachers have strong beliefs in activity-driven science and the use of hands-on inquires without focusing on what students are supposed to learn from the activities. They referred to this as "activitymania". Regarding hands-on experiments, Crawford (2014) pointed out that these do not in themselves guarantee meaningfulness and when used for their own sake, they are poor teaching. Other researchers (e.g. Appleton & Kindt, 2002; Furtak & Alonzo, 2010) have claimed that it is necessary to go beyond ''activities that work" because having fun is not enough, and students' understanding must also be considered (Furtak & Alonzo, 2010). Furthermore, researchers have claimed that inquiry is seldom found in classrooms (Capps & Crawford, 2012; Kim & Tan, 2011). Loughran, et al. (2004), for example, have pointed out that teaching science in general entails challenges that force the teacher to focus more on doing teaching than explicating the pedagogical reasoning. As mentioned before, teachers reflecting on their practice is an important aspect, and this is emphasised in my study of teachers working with IC-BaSE, presented in Paper III.

Challenges for teachers when using inquiry-based instructional strategies

Earlier studies (e.g. Yoon, Joung & Kim, 2011; Lee, 2011; Brand & Moore, 2011; Kim & Tan, 2011; Jones & Eick, 2007) among pre-service and in-service teachers have shown some problems and important factors to be considered. Some problems identified are that primary school teachers lack SMK in science and usually follow the book chapter by chapter and when using the inquiry method, this is usually done with the help of kits. In doing so, teachers keep a structured management style, according to Jones and Eick (2007).

Gillies and Nichols (2015) studied how primary school teachers' reflected when using inquiry-based teaching and how the implementation of inquiry could be supported. They found that the teachers were positive since they could see how the method had a positive effect on their students. Still, the teachers encountered several challenges. They were concerned about their lack of SMK, as well as the pedagogical skills required in using inquiry. They also found challenges due to the limited amount time for performing inquiry.

Appleton and Kindt (2002) presented challenges that primary school teachers find in science teaching. They mentioned that teachers often lack SMK, but the practical and time-consuming challenges of finding and gathering material impacted on the teaching. The teachers' solutions to the problems were to use activities they felt "safe" to undertake in terms of not losing control of the situation in the classroom. To stick to activities they were sure "worked", activities in which they knew the outcome, where nothing unexpected could happen. The teachers had experienced these kinds of activities during their own schooling, or during their teacher education. The teachers also mentioned the importance of collegial support, and Appleton and Kindt (2002) referred to studies suggesting a system of mentors scaffolding the beginner teachers. Despite the suggestion of providing support to beginner teachers, the problem of gathering equipment was still a problem for experienced teachers.

Kim and Tan (2011) discussed several challenges that primary school teachers face in their practical work. Teachers lack strategies to cope with unexpected results and follow the cookbook style to feel safe. They find the amount of time for inquiry during lessons to be too short, and they are afraid of having situations without control with messiness and chaos in the classroom doing inquiry. To be able to go through the curriculum is of major concern according to the teachers, and they do not think they have enough time to use inquiry-based strategies for that reason.

Many teachers also fear they will lose control using inquiry-based teaching, which has been shown in earlier studies (e.g. Crawford, 2007; Hohenstein & Mannning, 2010; Hutchins & Friedrichsen, 2012). Anderson (2002) discussed the barriers connected with inquiry teaching in terms of three dimensions: technical, political and cultural. The technical dimension includes the ability to teach with this approach, prior commitments (focus on textbook), challenges in assessment, the new roles for both teachers and students and inadequate education. The political dimension includes issues such as parental resistance, lack of resources, not enough in-service experiences, etc. The cultural dimension includes teachers' beliefs and values and issues such as being afraid of not covering the curriculum. Finally, Anderson (2002) stated:

> The task of preparing teachers for inquiry teaching is much bigger than the technical matters. Even though teachers need to learn how to teach constructively, acquire new assessment competencies, learn new teaching roles, learn how to put students in new roles and foster new forms of student work, the task of preparing teachers for inquiry teaching includes much more. The political and cultural dimensions are important as well. The task must be addressed in the political and cultural context of the schools in which teachers work (p. 8).

The practical constraints mentioned in research can be summed up as follows: *lack of time, how to handle big groups, finding materials* and *teachers being afraid of losing control* over the situation in the classroom (Jones & Eick, 2007; Anderson, 2002; Luft, 2001; Kim & Tan, 2011; Sormunen, Keinonen & Holbrook, 2014). In Paper II, the challenges among primary school teachers in using inquiry- and context-based teaching were investigated from a practical perspective.

An example of how inquiry-based teaching affects students (at middle and high school level) was presented by Duncan Seraphin, Philippoff, Parisky, Degnan and Papini Warren (2013). The teachers in the study used inquiry-based teaching with "real world" applications relating to issues of energy; they reported how their students showed interest and were very highly motivated. Many of the reports on the students' responses included the amount of time the students had spent on the project. Some enthusiastic remarks from the teachers are worth quoting:

> That day (of pinwheels) I could have walked out for 90 minutes, come back and they would have still been on task" or "I've never seen them (my students) work so long and hard and be bummed that class was over (p. 244).

The teachers explained that the energy science content was related to the real world and thereby made science relevant to the students. The findings presented by the teachers in the study by Duncan Seraphin and her colleagues (2013) are very similar to those presented in Paper IV. In other words, inquiry with contexts relating to real life can indeed stimulate students' interest in learning science.

During the studies presented in Papers I–III, the teachers participating used inquiry-based instructional strategies. However, their teaching included contexts from real life and has been referred to as IC-BaSE. In paper IV an IC-BaSE teaching model was used. Thus, an explanation of the notion context-based is also necessary.

The concept context-based education

What is meant by context-based teaching? The word context derives from Latin and the verb 'contextere' meaning 'weave together', and related nouns are coherence, connection and relationship. Bennett, Lubben and Hogarth (2007) defined the concept context-based in their review article as follows:

> Context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas (pp. 348).

Bennett and colleagues (2007) came to the conclusion that context-based approaches seem to be those that are relevant to:

- students' lives and interest at present
- situations students may encounter at some point in their lives
- technological developments and artefacts likely to be of interests to students
- students' possible future careers

Context-based teaching in chemistry education has also been defined through the different models discussed by Gilbert (2006). King (2012) defined context-based approach with a focus on chemistry education as:

> … a context-based approach is when the "context" or "application of the chemistry to a real-world situation" is central to the teaching of chemistry. In such a way, the chemical concepts are taught on a "need-to-know" basis, that is, when the students require the concepts to understand further the real-world application (p. 53).

The definition of a context-based approach by King (2012) is in line with the explanation provided by Bulte et al. (2006). They explained context as a starting point from where the teaching proceeds. Thereafter, the students will be aware of the knowledge they need in order to solve a given problem in the context.

The use of context in my studies is grounded in the definition by Bennett and colleagues (2007) who use context as a starting point in a three-step teaching model from the European PROFILES project to be presented later.

Context-based instructional strategies in primary school

In a recent study in New Zealand (Chen & Cowie, 2013), 11-year-old students learnt about birds in the context 'social circumstances', one of the context-based strategies presented by Gilbert (2006). This strategy has the potential to make science education relevant to students (Gilbert, Bulte, & Pilot, 2011). In the New Zealand study, the students grew more interested and reached a better understanding and ability to transfer knowledge from the context-based teaching to new situations with related contexts (Chen & Cowie, 2013). Gilbert (2006) emphasised that the context really needs to be meaningful for the students. Newton (1988) claimed that the individual perspective might be more important for younger children, but societal dimensions get more interesting and relevant as the child grows and matures.

Challenges with context-based instructional strategies

As already mentioned, the choice of context is important, which could be considered as a challenge (Gilbert, 2006). Another aspect that has also been raised is the risk that context-based approaches only have affective responses on students (Marks & Eilks, 2010). This risk was highlighted by Sevian and Talavanquer (2014) who claimed that the risk in using context-based instructional strategies is that the content to be taught might become buried under the context used to stimulate learning. Additionally there is research (e.g. Pilot & Bulte, 2006) in which it has been argued that the distinction between context, content, topic, modules or themes is sometimes confusing.

Summarising IC-BaSE as instructional strategies

In this section I have presented arguments for using IC-BaSE as instructional strategies, the main reason being to stimulate students' interests in learning science. I have also featured definitions of the concepts inquiry- and context-based. Examples of how these instructional strategies have been used and challenges in using them have been provided. The uses of both strategies have mostly occurred at secondary school level, but some examples from primary school have also been given. Finally, the challenges, especially for primary school teachers, of using the strategies have been discussed.

Fourth zoom - Purposes of choosing certain instructional strategies

The fourth and final level of zooming in on my research question in perspectives of earlier research is related to purposes in science teaching. The zoom has specifically been on purposes of choosing certain instructional strategies. Schneider & Plasman (2011) found that when teachers described the purposes of science teaching in general, it was to prepare students for future studies, to gain students' attention, to develop their skills (in inquiry) and to support students' understanding. However, the purposes differed between primary and secondary school teachers. The former emphasised the development of students' curiosity and that they should enjoy teaching, while the latter maintained that students should develop appreciation for the usefulness of science (Schneider & Plasman, 2011).

Purposes of using inquiry-based instructional strategies

Crawford (2014) mentioned that inquiry-based teaching has two purposes: the pedagogy of inquiry and the learning outcome. The pedagogy is about using inquiry as a method to engage students in designing and carrying out investigations, and the learning outcome refers to inquiry as part of understanding the nature of scientific inquiry. In other words, inquiry is either used as practice, learning the skills, the practical part of inquiry, or as learning about the content of inquiry, or as she puts it:

> An important idea is that inquiry should be thought of not only as a teaching approach but also as content to be learned (Crawford, 2014, p. 522).

Bhattacharayya, Volk and Lumpe (2009) claimed that inquiry is more than a procedure or a method, but rather a process of investigating how, why or what, and making sense of the findings. In the multi-authored paper by Adb-El-Kahlik et al. (2004), views on inquiry from different countries are presented. Lederman contributed in the paper with the view of the US and emphasised that teachers should not only use inquiry as a method, but also to help students understand inquiry as content. He claimed that students might not learn about inquiry simply by doing, rather it needs to be made explicit.

Reasons to use inquiry in teaching have also been presented in reports such as one from the EC (2007), as well as suggested by several researchers (Bennett & Holman, 2002; Bulte et al., 2006; Chen & Cowie, 2013; Gutwil-Wise, 2001; Kennedy, 2013; Osborne & Dillon, 2008; Parchmann et al., 2006). The idea that scientific inquiry is essential because of the need for future scientists and the development of scientifically literate citizens has been put forward by several researchers (e.g. Lederman, Antink & Bartos, 2014; Millar, 2006; Millar & Osborne, 1998).

Lin, Hong and Cheng (2009) have argued that in teaching science, using inquiry is a starting point for increasing student motivation to learn, claiming that if students are involved in the planning process, they are more likely to get involved in the task. Cuevas, Lee, Hart and Deaktor (2005) have suggested that a reason for using inquiry is to apply research skills, whilst Luera and Otto (2005) emphasised that inquiry can increase the learning of content. Researchers present different arguments. However, the justifications listed by Crawford (2014) are a summary of the arguments mentioned above.

- Inquiry aligns with how people learn science
- There is a need for inquirers
- Inquiry is a means to understand how science is done
- Inquiry is a means to develop young peoples' interest in science
- Inquiry is an important means to understand that science itself is changing
- Inquiry addresses the need for citizens to be able to make decisions related to controversial societal problems

The importance of students knowing the purpose of inquiries has been advocated by Wickman (2006, 2014a), who suggested that if students do not know the purpose of what they are doing, they will probably not experience science as something meaningful. Högström, Ottander and Benckert (2012) also claimed that if students are supposed to understand what they are going to learn from an inquiry, the teacher must make the goals clear to them. However, Keys and Bryan (2001) have pointed out that there is little knowledge about teachers' views on goals and purposes of inquiry. Lederman and colleagues (2014) also argued that there is a difference between doing inquiry and understanding about specific characteristics of inquiry. They claimed that students are often asked to control variables when conducting inquiry. However, many of the students do not necessarily know the purpose of doing so. Referring to the National standards (NSES and NGSS), they pointed out that:

> ... doing something alone does not engender an understanding of what is being done (Lederman et al., 2014, p. 72.).

To summarise the science teaching purposes and inquiry-based approaches, I return to Crawford (2007), who specified three purposes of inquiry-based teaching. It is important that students can:

- Develop their abilities to *do* inquiry
- Gain understanding *about* inquiry
- Develop understanding of concepts *through* inquiry

When Wickman (2014) discussed the importance of students knowing the purpose of the activities, he also related this to their interest in learning and need to enjoy what they are doing during the lessons. I interpret his argument to mean that if students know the purpose of the activities, it is easier for them to enjoy doing them. Student's wishes to know the purpose of activities in school are not restricted to inquiry activities but apply generally. Johansson (2014) discussed this in terms of two levels of purpose: one, close to the students (adjacent), and the other, the teacher's purpose (overall) based on the goals of the curriculum. She presented an example: If the overall purpose is that students are supposed to learn about properties of solid and liquid substances, the students' close purpose can be to find out what will happen during a specific investigation of how a substance reacts. Furthermore, Johansson (2014) argued that when working with inquiry-based teaching, it is also necessary to make connections to contexts.

Purposes of using context-based instructional strategies

Context-based courses have been developed since 1980s (Bennett et al., 2007). The purpose of a context-based approach in science education is to bridge the gap between learning in school and everyday life (Gilbert, 2006; Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013) and to make science education relevant to the students. Hofstein et al. (2011) argued that besides making problems authentic and relevant, the problems provided in context-based approaches require more complex thinking. Nentwig et al. (2007) argued that context is not merely a decoration used to motivate students, but rather a red thread along with the investigation of the issue studied. Marks and Eilks (2010) claimed that too much emphasis has been on the affective aspects of context-based teaching.

Bennett et al. (2007) also mentioned the aim of using context-based education. According to them, the main idea is that the method will motivate students and make them feel more positive about science by helping them see the importance of what they are studying. Another aim is to improve students' learning of science. According to Bennett and colleagues (2007), their review findings indicated more positive attitudes towards science, among students using the method context-based teaching. When it comes to learning improvement, the results were, however, comparable to traditional approaches. All the studies were on students aged 11–18, and indicated that some caution is needed in interpreting the findings in their review, since all contexts may not have the same effect on all students. Their recommendations for further areas of research were to explore the effects of particular types of contexts.

Context-based education has mainly been used with secondary school students and in chemistry and physics courses. Some known projects using a context-based approach are the *Salters* in UK, *Chemie im context* in Germany, *Chemistry in practice* and the *Physics Curriculum development project (PLON)* in the Netherlands. As already mentioned, the reason for developing this teaching approach was to improve students' engagement in learning (chemistry) and to make the teaching relevant to the students. Discussing the notion of relevance from the students' point of view, Gilbert (2006) argued that it is important not to choose *any* context when teaching, but also to make sure that the context chosen responds to the learner's needs, and emphasised that it is necessary to keep in mind that not every context is interesting to students, and that different groups of students might have different interests.

As argued above, the choice of context is important because contexts make science relevant to students and give them a sense of why they should learn the required material. Furthermore, students have shown to be motivated when science teaching is related to aspects of real life (Bybee & McCrae, 2011).

Intended purposes versus experienced purposes

The relation between teachers' *intended purposes* of teaching, or of choosing certain instructional strategies (inquiry- and context-based) and students' *experienced purposes* (based on ideas of Marton & Pang, 2006 and Marton & Ling, 2007) is part of the study presented in Paper III.

To know the purpose of choosing a certain instructional strategy is a central part of a teachers' competence (Lidar & Lundqvist, 2014). A teacher must be aware of what he or she is doing and why. Additionally, it is essential that teachers' intended purposes are the same, or at least close to the students' experienced purposes if learning is to occur according to the goals (Wickman & Östman, 2014).

As the concepts *intended* and *experienced* purposes were used in Paper III, I need to explain where these notions come from. The analysis of data in the paper was performed on the basis of the theoretical framework presented by Marton and Pang (2006) and Marton and Ling, (2007) in terms of *intended, enacted* and *experienced* purposes of the teaching. In the research approach called "Learning study", the notions *intended, enacted* and *lived object of learning* have been used (Marton & Pang, 2006; Marton & Ling, 2007). The *intended* object of learning is what the teachers intend their students to learn. The *enacted* object of learning is what is actually happening during teaching, and finally, *the lived* object of learning is what the students experience from the teaching. In my third study, these notions are used although in a modified version. Since the study did not investigate students' learning, the *purposes* of teaching were discussed instead. Also, instead of using the notion *lived object of learning*, students' responses as *experienced* purposes of teaching are discussed in my third paper.

Summarising the purposes of choosing certain instructional strategies

In this section, the fourth and final zooming in on aspects of earlier research related my studies have been discussed. I have presented arguments from previous research about the importance of knowing the purpose of why students are supposed to do certain activities, in this case, inquiries. The concepts *intended, enacted,* and *experienced* purposes, which I use in Paper III, were explained.

Summarising the theoretical framework

The focus of my studies is on primary school teachers' reflections on science teaching and the use of inquiry- and context-based teaching approaches. Several researchers have investigated and theorized on teachers' needs and development of PCK (e.g. Shulman, 1986, 1987; Nilsson, 2014), but research at the primary school level is still a necessary gap to fill (e.g. Appelton, 2006). Previous research has also pointed to the need for primary school teachers to develop instructional strategies (e.g. Roth, 2014), which is one of the components of PCK. Arguments for using inquiry and contexts in science education were formulated already in the 1800s by pragmatists. However, pragmatic ideas are still of interest and form a basis for justifying inquiry- and context-based teaching. Even within the field of research on inquiry- and context-based education there is a need for more research at the primary school level. Therefore, I hope that this thesis will serve as a contribution to filling this gap. The theoretical background described four different zooming in on my overall research question. After presenting the context of my studies, the methods used, and the results of each of the papers, I relate different theoretical perspectives to the research question in my discussion.

The research context

The studies presented in this thesis were all performed in a Swedish context. Therefore a brief presentation of the Swedish school system is provided. The use of IC-BaSE in Sweden, as presented in earlier research also needs to be described. In all four papers presented in this thesis, a teaching model from a European founded project named PROFILES* was used. (The acronym stands for Professional Reflection-Oriented Focus on Inquiry-Based Learning and Education through Science). Hence, the PROFILES teaching model is also presented.

The Swedish school system

Education in Sweden is mandatory from the ages 7 through 15, and divided into primary school (grades 1-6) and lower secondary school (grades 7-9). All schools, whether private or run by the local authorities, are under an obligation to adhere to the national curriculum (Swedish National Agency for Education, Lgr 11). Upper secondary education is voluntary. However, most students continue studies at this level.

IC-BaSE in Sweden

In a Swedish context, the national curriculum for the science subjects, has similar formulations as those in NGSS (2013). The description of biology, for example, includes the following aims:

> Through teaching, students are given the opportunity to ask questions about nature and humans based on their own experiences and current events. Furthermore, education should provide students with opportunities to seek answers to questions using both systematic surveys and various types of sources. In this way, the teaching should help students develop a critical thinking about their own results, the arguments of others and different sources of information. Through teaching students should also develop an understanding of the claims can be tested and evaluated using scientific methods (Swedish National Agency for Education, 2011).

*Information about PROFILES can be found at http://www.profiles-project.eu/

When inquiry-based science education is practised in primary school in Sweden, it is common to use the teaching programme *Science and Technology for All (Naturvetenskap och Teknik för Alla – NTA**).* The programme has its origins in the US and was implemented in Sweden in 1997. In this material, context is not used, but rather longer and broader themes, e.g. ''float and sink''. The themes are developed through student assignments involving investigations based on a given question. In Sweden, researchers (e.g. Anderhag & Wickman, 2007; Andrée & Lager-Nyqvist, 2012; Johansson, 2012) have studied the use of the *NTA* model as an instructional strategy. In Paper I, the *NTA* model was discussed since it was the only instructional strategy used by the primary school teachers in the study before the CPD programme.

NTA has been received in a positive way, and teachers feel strong support in their teaching using the material (Johansson, 2012), especially since all the material and equipment are delivered with instructions in boxes. However, Johansson (2012) found that primary school students had problems in understanding the aims and purposes of the inquiries. She also came to the conclusion that more research on inquiry-based teaching in primary schools is needed. Studies on the purposes of inquiry in Sweden, have shown that most teachers are not aware of inquiry as a learning outcome. Lunde (2014) found that for most teachers this was a novelty, as they had mostly thought of inquiry as a method used to confirm scientific laws or concepts.

The same conclusions were drawn by Högström et al. (2012), who found that inquiry-based activities have mostly been regarded as a teaching method to strengthen the learning of content and to stimulate interest in learning science. In addition, they found that teachers were not aware of scientific methods being part of the learning outcomes.

**Information about NTA can be found at http://www.ntaskolutveckling.se/

The use of the context-based teaching approach is not explicitly emphasised in the current Swedish curriculum. The approach has potential in making science education relevant to students. This seems important, as a recent survey (Sokolowska, Meyere, Folmer, Rovsek, & Peeters, 2014) has shown a great drop in students' positive attitudes towards science education between the ages of 8 – 11. Sokolowska and colleagues (2014) focused particularly on aspects of learners' attitudes towards science and technology subjects. The study included ten countries in Europe, among them Sweden.

The three-step teaching model from PROFILES

Based on the important roles of IC-BaSE in promoting student interest in learning science and making students understand scientific processes, the PROFILES project aimed at combining these approaches into a three-step science teaching model (Holbrook & Rannikmäe, 2010; Vaino, Holbrook, & Rannikmäe, 2012). The model consists of:

1. Contextualisation – a context with a problem from real life with familiar scenarios is given to the students
2. De-contextualisation – the inquiry step with scientific investigations used to solve the given problem
3. Re-contextualisation – initial issue is revisited, conclusions drawn and students show how they can incorporate their acquired knowledge from the second step to make decisions and arguments

To my knowledge, the model has mainly been used in secondary schools, and I was interested in testing the model at the primary school level, which was done in the studies presented in Papers I–III. The teachers were free to choose the context. The reason for this was not to interfere too much with their planning. The teachers taught in different grades (4–6) and at different stages of the curriculum. Their choices of contexts were covering CK about space (goals in the curriculum for physics), soap (goals in the curriculum for chemistry), and food (goals in the curriculum for biology). Finally, a context about a school yard covered with ice and the problems it caused (goals in the curriculum related to knowledge about the water cycle) was used in paper III.

In Paper IV, the model was used to investigate how students responded when the context was a crime technology case.

CPD programme

Based on the knowledge from earlier research (Viellegas-Reimers, 2003), a CPD programme was organised and served as a foundation for the studies presented in Papers I and II. It was important to connect with school practice, thus, the programme lasted for five months, had time for reflections including both individual and group discussions. The teachers chose their own content which they wanted to focus on, thus not interfering too much with the work they had already planned for their students. During the programme, the teachers had support from each other, as well as from the CPD provider. The teachers had volunteered to participate and were willing and curious to learn more about how to teach science. The design of the programme is further described in Paper I.

Aim and research questions

Based on earlier research arguing for teachers' need for PCK, especially at the primary school level, the aim of this thesis was to develop an understanding about primary school teachers´ knowledge about IC-BaSE from different perspectives: what it is, how to use it and why these strategies should be used. The main research question is:

How do primary school teachers reflect on Inquiry- and Context-Based Science Education as a framework for teaching and learning in the primary school classroom?

The separate research questions in each of the papers are presented below.

Paper I:

- How was the component of PCK concerning *instructional strategies* developed and captured from primary school teachers' experiences and reflections when using the IC-BaSE teaching model from PROFILES in their classrooms?

Paper II:

- What are the challenges of working with IC-BaSE at primary school level?

- How can these challenges be solved, according to the teachers?

Paper III:

- What are primary teachers' objectives for choosing inquiry and context-based instructional strategies?

- What is the relation between the instructional strategy choices and the teachers' knowledge of students' understanding and intended learning outcome?

Paper IV:

- How do secondary school students respond to an IC-BaSE three-step teaching model?

METHODS

The four studies presented in this thesis were performed with different approaches. The studies in Papers I, II and III were qualitative and IV was quantitative. Thus, the thesis includes both quantitative and qualitative studies and discussions of these methods. The methods applied in each of the studies were guided by, and dependent on the research questions. Each of the methods used for data collection and analysis are presented in the following sections.

Data collection methods

Group discussions

In Papers I and II, group discussions were used in four out of five workshops during a CPD programme. The discussions aimed to catch participants' reflections on different issues relating to inquiry- and context-based teaching, as well as science teaching in general. The discussions were audio recorded and transcribed. To maintain anonymity, teachers were de-identified in the transcript process. Each group discussion lasted between 15 to 45 minutes depending on the number of issues discussed. Altogether, seven recordings were made in each group, which consisted of four members per group. The members in the groups were randomly chosen. The groups were retained throughout the whole study. The questions guiding the teachers through the discussions are found as an appendix in Paper I.

Interviews

In Paper III, semi-structured interviews, according to Kvale (1997), were conducted with two teachers participating in the study. The interviews were performed in an attempt to catch teachers' reasons for choosing IC-BaSE as an instructional strategy in relation to their knowledge about students' understanding. The interviews were audio-recorded and transcribed. Content Representation (CoRe) developed by Loughran et al. (2004) served as a base, framing the questions in the interviews together with students' reports on how they experienced the teaching. Table 1 presents the CoRe used during the interview. The model is modified due to translation into Swedish, but the meaning of each item is the same as the original.

Portfolios

Based on earlier studies on how portfolios can be used as tools for reflection (e.g. Harrison et al., 2008; Viellegas-Reimers, 2003), this was used as part of data collection. In Papers I and II, teachers participating in the study were told to write their individual portfolio during the CPD programme. They were asked to reflect on what was presented during the workshops on IC-BaSE and the work with the PROFILES modules, both in the planning and performance phases. The portfolios were handed in after the last workshop and were used to catch the individual reflections as well as for the triangulation of data collected from group discussions.

Field notes

In Paper I, field notes were taken by both authors during the teachers' presentations at the fifth workshop on how teaching modules had been performed in the classrooms. Data were collected based on two aspects, namely experiences expressed by the teachers themselves and the teachers' interpretations of students' experiences. The field notes were used as triangulation of data and were taken based on instructions identified by Cohen, Manion and Morrison (2011). Notes were also taken by the first author during activities in Paper IV.

Content-Representation (CoRe)

In Paper III, Content Representation (CoRe) was used. This tool has been described in the theoretical background aiming to identify teachers' PCK. The CoRe filled in by the participant teachers contained the items presented in Table 1. Each of the items is connected to a *Big idea* of what is going to be taught. A teacher can have several *Big ideas* in a specific field. The items used in the CoRe where slightly modified from the original due to interpretations from English to Swedish, although still with the same meaning.

Table 1. The items used in a modified CoRe.

1. What do you expect students to learn about this specific knowledge?
2. Why is this important for students to learn?
3. What more do you know about this idea (knowledge you don't consider needed for students)?
4. What difficulties could occur in connection with the teaching of this content, i.e. what problems could arise in the educational situation?
5. What is your knowledge of students' conceptions/misconceptions of the subject and how do these influence your teaching?
6. What other factors could influence your teaching in this field?
7. Which teaching strategies will you use and why have you chosen them?
8. In what ways do you think you could facilitate students' comprehension?
9. What ways will you use to assess if students have learnt what you expect them to have learnt?

Questionnaire instruments

In Paper III, a questionnaire with six open-ended questions was distributed to students to investigate how they had experienced the purposes of some science lessons. The results of the questionnaire were used to stimulate teachers' reflections on their teaching and served as a foundation in an interview with the teachers. The questions were pre-tested with four students from other classes before being used for data collection. The pre-test was performed to check students' understanding of the questions. The questions are found as appendix in Paper III.

In Paper IV, a Likert scale questionnaire from the PROFILES project was used for data collection. This questionnaire investigated how students responded to the three-step teaching model from PROFILES. The questions compared students' responses to the model versus their experiences of ordinary lessons in science and their ideas of ideal science lessons. The original questionnaire from PROFILES, developed by Bolte and Streller (2012), was adapted to the Swedish context. The term *ideal lesson* in the original form was changed to *perfect lesson* to make Swedish students understand this notion better. The items of the three different sections were the same; thereby, it was possible to make comparisons between the different kinds of lessons. The scale had a ranking from one to seven, from *not important at all to me* to *very important to me*. The questionnaire is found in Paper IV.

Data analysis

The analysis of the group discussions in Papers I and II were performed with the same approach as the analysis of the open-ended questionnaire, using content analysis to find categories in the data processing. The content analysis was performed inductively. In paper I the analysis was performed euqually by the two authors. In paper II the first and third author conducted the analysis. In both papers, the authors performing the analysis agreed from the start to search for teachers' comments that included a comparison of before and after the workshops in the CPD programme. The research questions in each of the studies presented in Papers I and II were the guiding principle during content analysis. Therefore, audio-recordings were performed both before and after workshops in the CPD programme and after the teachers had used the IC-BaSE three-step teaching model with their students. The same procedures were used in analysing the teachers' individual portfolios in Paper I and II as well as the field notes used in paper I.

In Paper III, the transcripts from the audio-recorded interviews were analysed based on content analysis. First and third author performed the analysis and used the same procedures as already described. In this study, the analysis was not only inductive, but also combined with predetermined concepts based on earlier research by Marton and Pang (2006) and Marton and Ling (2007), thus also deductive. Marton and colleagues (2006, 2007) used the concepts *intended, enacted* and *experienced* objects of learning. However, these concepts were modified in Paper III to focus on *objectives of* teaching rather than students' learning. Instead of using the notion 'lived', students' responses were discussed as *experienced* objectives of teaching. Hence, data analysis was based on teachers' *intended objectives of teaching*, the *enacted teaching* and *students' experience of objectives of teaching*. Finally, a last category was made based on the research question and the relation between the three concepts described above. This category was classified as *the relation between intended, enacted and experienced objectives of teaching*.

In the questionnaire conducted with students in Paper III, consisting of six open-ended questions, content analysis as described by Miles and Huberman (1994) was used. This analysis was performed by the first and third authors independently. Results were then discussed between all three authors until consensus was reached.

The analysis of the questionnaire used in Paper IV was performed using the statistical programme SPSS software (version 12). One-way ANOVA was conducted to compare the different forms of science lessons compared in Paper IV.

The participants in each of the studies

In Papers I and II, an invitation was sent to primary school teachers who had previous experiences of using the *NTA* materials, thus having some experience of science teaching and especially of inquiry-based instructional strategies. The reason for this was the aim to explore how primary school teachers could develop their knowledge about inquiry-based science education, and also to teach science using contexts from real life. A total of 29 teachers were invited and 12 of them accepted to take part in a CPD programme and my research project. The teachers were informed about the ethical guidelines, which are described separately.

Two of the teachers who participated in the CPD programme were interested in the future development of their practice and cooperation in my research project. They participated in the study presented in Paper III together with their students (two school classes, one from grade 5, the other one from grade 6).

Finally, in Paper IV, 105 grade 9 students (15 years old) responded to the questionnaire used as data collection. They were all volunteers, informed about the ethical rules and guaranteed anonymity. They were invited with their school classes to test the IC-BaSE three-step teaching model. Thus, invitation was originally sent to their teachers. Specifically, the invitation was sent to all schools in the region with secondary school students. Hence, the first classes that accepted the invitation became part of the study. All students in the classes also agreed to answer the questionnaire. No relation existed between the students and the researchers. Teachers from a university guided the students through the work with the model and no relation existed between them and the students participating in the study.

Validity and reliability of the studies

The discussion of the *validity* and *reliability* of my studies will be done separately for the quantitative and the qualitative studies, respectively. It has been argued that the concepts *validity* and *reliability* cannot be used when discussing qualitative studies (Lincoln & Guba, 1985) and that there are other concepts more suitable such as trustworthiness and authenticity. Larsson (2005) has presented yet another approach in discussing the quality of qualitative studies. He maintains that criteria for quality in qualitative research should be divided into three aspects: qualities in the work as a whole, qualities of results and validity criteria. Robson (2011) argued that:

> The attempt to rename and disclaim the traditional terms continues to provide support for the view that qualitative studies are unreliable and invalid (p. 155).

Since the studies are both quantitative and qualitative, I prefer to discuss them using the same concepts, even though I am aware that quality cannot be measured in exactly the same way in the two approaches. Both Robson (2011) and Cohen et al. (2011) preferred to use the traditional concepts (validity and reliability), irrespective of the method used.

According to Cohen et al. (2011) and Robson (2011), the basic definition of the concept validity would be answering the question: 'Have we measured what we intended to measure?' The concept reliability represents 'whether the study is trustworthy,' or, put in other words: 'Would the results be the same if we repeated the study?' These questions constitute the basic foundation of the concepts. However, each of the concepts has many forms. Cohen et al. (2011), for instance, listed 20 forms of validity. When I have discussed the concepts with colleagues, it seems as if the use of them is complicated, and there are also complex interactions between the concepts. However, I will present a picture of my reflections on how I have tried to design and perform the studies with the aim to obtain good quality.

In the quantitative study of my research (Paper IV), the data collection was conducted through a questionnaire. The development of the questionnaire had already been done by other researchers (Bolte & Streller, 2012). The questionnaire had been validated in ealier studies. Since the original questionnaire was developed in a non-Swedish context, some adjustments were made before distribution. In the study, the respondents were students who had participated in an activity designed to test an IC-BaSE teaching model. The Likert scale questionnaire used had a scale ranked from one to seven, from *not important at all to me* to *very important to me*. The invitation to attend the activity had been sent to all lower secondary schools in the region. However, only the first five classes which accepted the invitation to participate were part of the study because of time restrictions. The teachers made the decision to participate in the activity, but the students were informed that they were free to fill in the questionnaire or not. They were also informed that the questionnaire was part of a research project and that their responses would be anonymous. All students filled in the questionnaire. Since I was present during the data collection, the students had the opportunity to ask me if there were any questions they did not understand. I had never met the students before the activity and there was no particular relation between us. The questionnaire was coded manually before analysed. Because the questionnaire was coded manually, random samples were taken on every fifth respondent to double check that the coding had been correct. A traditional tool used in statistical analysis measuring reliability is Cronbach alpha, which is a measure of the internal consistency among the items. Based on earlier research, Cohen et al. (2011) claimed that a value of Cronbach alpha is reliable between 0. 67 – 0.8. When testing reliability using Cronbach alpha, the value was 0.77, thus considered as reliable results.

The studies in Papers I, II and III were qualitative. They all had the character of a case study. Although the participants were volunteers, they were invited through a special network of teachers having earlier experiences of inquiry-based teaching. Cohen et al. (2011) have defined case studies as striving to portray what a particular situation is like and by capturing thoughts of the participants through their experiences. They argued that case studies often employ many types of data, which I also used in these studies by collecting different forms of data.

However, as I was interested in investigating how primary school teachers responded to the use of IC-BaSE, it seemed natural to invite teachers with at least some experience of inquiry-based work. Since the participating teachers in my studies were part of a network for teachers interested in science and technology, it is necessary to recognise that this may affect the results. The results from the studies cannot be generalised for this reason, and also because of the low number of teachers who participated. Still, I believe there are many primary school teachers in Sweden with a similar background; therefore, the results should be of interest.

The data collected in Papers I and II were mainly based on audio-recordings of group discussions. Participants had no relation to the researchers before the study. However, in order not to influence the participants during the discussions, none of the researchers were present during the group discussions. A disadvantage of not being part of the group discussions was not having the opportunity to ask if there was anything the teachers discussed that was difficult to understand. Still, the audio-recordings captured interesting data.

My role as a researcher

Discussing the validity of my qualitative studies, I have tried to use *thick descriptions* (Cohen et al., 2011) of the whole research process in each of the studies. The sampling was purposive (Cohen et al., 2011; Robson, 2011), and to be able to argue for internal validity, i.e. credibility, I have tried to show how the results presented are supported by data by presenting evidence from the participants' contributions in the form of quotations. When reliability is discussed in qualitative research, the concept interrator reliability is often applied (Cohen et al., 2011). In all of my qualitative studies, this method was used. Data were analysed separately by co-researchers and me, and discussions were conducted until we had reached agreement (Cohen et al., 2011). In Papers I and II, triangulation of data (Cohen et al., 2011; robson, 2011) was also performed using group discussions, the participants' individual portfolios and field notes (only in Paper I) from a workshop to compare and strengthen data collections and analysis.

During the CPD programme (presented in Papers I and II), there was no particular relationship between me as a researcher and the participants from the start of the programme. Other teachers were invited to teach in the programme, and I tried to stay in the background only being responsible for the design of the programme and the data collection. As mentioned before, I also did not attend the group discussions in order not to affect the outcome. However, it can never be argued that my role as a researcher was not affected by the fact that I was responsible for the programme. Besides collecting data, an implicit aim was to stimulate the TPD in teaching science, and motivating the teachers to try the IC-BaSE teaching model. In other words, my role as a researcher was probably affected by my role as a teacher educator.

At the same time, I was afraid of interfering and affecting the teachers too much in the role as educator; therefore, I did not challenge the teachers during their discussions or the interviews by asking them provocative questions. Looking back, I could have done this more, but on the other hand, the results could then have turned out somehow differently. If the teachers discussed problems, I was afraid of providing the solutions, and this is not recommended in the processes of reflection (Rodgers, 2002). As a matter of fact, Rodgers stipulated that a norm for reflection processes was that giving advice was prohibited, especially after a problem has been presented. In this respect, I would argue that it was a good choice to remain as an observer and researcher, avoiding the risk of acting as an educator.

Kvale (1997) discussed the problem of objectivity in qualitative research related to the use of interrator reliability as a tool, which I have discussed earlier as a way to ensure good quality. We are all humans, researchers and participants, and our interactions and values, as well as the social and cultural context we are part of, influence what we communicate and how we interpret each other.

Ethical considerations

In part, many aspects of ethical considerations have, to some extent, already been mentioned in the methods section above. Summing up, the ethical guidelines of the Swedish Research Council have served as a basis for the ethical aspects in all of the studies. The four rules of research regarding information, consent, confidentiality and use of data were followed. All of the participants were informed that their participation was voluntary, and it was emphasised that the participants' identities would be protected throughout and after the completion of the projects. All collected data were handled in such a way that the participants' identity would not be traceable and the data kept safe. Participants were also informed that the data would be used in my research.

RESULTS

The results of each of my papers are only briefly presented, as the complete versions are available in the papers, included at the end of this thesis.

Paper I. Primary science teachers' reflections on inquiry- and context-based science teaching

In this study, twelve teachers reflected on the inquiry- and context-based strategies used in primary schools. The teachers participated in a CPD programme. During the programme, they were introduced to a teaching model from a European project, in which IC-BaSE strategies were combined. The research questions related to teachers' reflections on these teaching strategies, and whether they found the model to be useful in primary schools after testing it with their students.

Results showed that teachers found the new teaching model to be a useful complement to their teaching. Before the CPD programme, they were only aware of one instructional strategy, the use of *NTA*. After the programme, they found that the IC-BaSE model engaged their students and improved their skills in planning inquiries. However, their discussions also showed that they did not reflect on the choice of strategies, purposes and aims relating to students' understanding, or on the content to be taught.

Before the CPD programme, teachers discussed the use of inquiry mainly from the perspective that students enjoy practical work and inquiries as a way of students to have fun. After the programme, they found more reasons for using IC-BaSE, and discussed the importance of also knowing *why* inquiry is performed from a learning perspective. Futhermore, the teachers discussed practical aspects of science teaching. Before the programme, their focus was on all the practical challenges, and after the programme they had developed their own solutions. Since the discussions about the practical aspects of IC-BaSE were extensive, a separate paper (II) was written, focusing only on these.

Paper II. Enhancing primary science: An exploration of teachers' own ideas of solutions to challenges in inquiry- and context-based teaching

The data for this paper were collected in the same CPD programme as in Paper I. The participants were thus the same, twelve primary school teachers. As part of the CPD programme, the teachers discussed challenges in IC-BaSE. Content analysis showed that the challenges teachers experienced were mainly practical problems relating to*: how to find contexts, lack of time, handling big classes, students working at different paces, handling materials* and *the teachers' need for control.*

The teachers also presented their own ideas of solutions to the challenges. They believed that finding appropriate contexts should be done together with their students. However, they emphasised the need to always connect to the curriculum. At the end of the CPD programme, when the teachers had tried an IC-BaSE model with their students, they hardly discussed the issue of lack of time. Rather, they agreed that always when starting something new more time is required, but they also had ideas on how they could cooperate and help each other. One of their ideas was to share modules they created, based on the particular IC-BaSE model, on a website.

Furthermore, the teachers had some solutions for how to handle big classes when working with inquiry-based learning. They discussed how the challenge of students working at different paces could be solved by using a range of stations with different tasks, which not all students were required to do. Another solution was to have a repetitive system throughout the lesson, in which the students worked for some minutes and then discussed jointly for a few minutes with the whole class. This was also a way to maintain control of the class and avoid having students losing focus and interest. However, the teachers preferred to have smaller groups for inquiry-based activities. Finally, the teachers presented ideas to the challenge of gathering and collecting materials for inquiry-based lessons. Their main idea was to use a system that they already had of the pre-packed *NTA* boxes. They also discussed how they could convert some of the *NTA* themes and work with them according to the IC-BaSE model presented during the CPD programme.

Paper III. Why inquiry? – Primary teachers´ objectives in choosing inquiry- and context-based instructional strategies to stimulate students´science learning

This study investigated two primary teachers and their objectives in choosing inquiry and context-based instructional strategies as well as the relation between the choice of instructional strategies and the teachers' knowledge of students' understanding and intended learning outcomes. Content representations designed by the teachers and students' experiences of the enacted teaching served as foundations for the teachers' reflections during interviews.

The results showed that the teachers' intended teaching objectives were that students would learn about the water cycle and the states of water. They did not have any particular arguments as to why they wanted to use IC-BasE beyound referring to how this instructional strategy had engaged their students earlier. During the enacted teaching it seemed as if the inquiry process was in focus and this was also how many of the students experienced the objectives of the activities. The students thought that the learning objective was to develop knowledge about how to plan and develop inquiries. This objective was written on the instructional sheet given to the students. In other words, there was a gap between the intended and experienced objectives.

Still, investigating the teachers' objectives of choosing certain instructional strategies, they were satisfied with the choice of using the IC-BaSE model since this engaged their students. However, this intention was not explicit from the start. Furthermore, the teachers claimed that the strategy was good because the inquiries also included discussions among the students and did not focus on the doing. Yet, at the same time the teacher in grade five argued that her students had been focused on *doing*. The teacher in grade six claimed that her students had been interested in *understanding* the content. Both teachers argued that the students' experiences were a result of a natural process. They claimed that in grade four students are focused on the doing and gradually students develop a desire to understand. The teachers argued that this is a matter of students becoming more mature. In other word, the teachers thought it was natural that students in grade six were more interested in understanding.

When the teachers were confronted with the students' experiences, they had several explanations to why the students did not report the same objectives of the teaching as intended. The teachers claimed that the students had understood a great deal more than what they had written, and that this was shown during the discussions in the lessons. However, hardly any relation was found between the teachers' choice of instructional strategies and their knowledge about students' understanding, with the exception that the teacher who also added drama wanted to support her students' understanding of the states of water.

One of the teachers agreed that her students had been focused on the inquiry, possibly because of the text on the instructional sheets about the learning objectives, which focused on the inquiry process. In the third and final interview there were a few comments indicating this aspect. The teachers also mentioned how the students could develop their knowledge in planning inquiries, thus adding to the purposes of using IC-BaSE after they had used it.

The teacher who added drama also argued that the choice was successful in supporting students' understanding, as intended. However, the teachers realized that if they wanted to teach about the chosen "big ideas", additional inquiries were needed to give the students the opportunity to experience the state of water in the form of gas, for example.

Paper IV. Students' responses to a context- and inquiry-based three-step teaching model

This case study aimed to present a combined context- and inquiry-based teaching approach, using the PROFILES three-step teaching model, and investigated Swedish students' responses to the activity. The 105 students participating in the study were aged 15. The results showed that students were more positive to this model of science teaching than to their previous science lessons in school in relation to their idea of a perfect lesson in most of the questionnaire items. The students did not consider the context used, a CSI case, relevant to their everyday life, but to society.

The results of the field notes also showed that students were engaged during the activity using the three-step model, asking questions about related jobs and education. The three-step model proved to be a suitable teaching model to enhance students' affective response in this case study.

In Figure 1, the results of a Likert scale questionnaire, shows the comparison of students' reflections on their school lessons in science, their ideas of a perfect science lesson and how they experienced the activity with the inquiry- and contex-based three-step teaching model. The students responded to how (1) enjoyable they found the lesson, how they could (2) understand the content taught, and if they had (3) time to reflect on the content. Furthermore, they responded to whether they found the lesson (4) useful to themselves in their everyday lives, (5) useful to society and if they considered themselves as being (6) active during the lessons.

The students' responses to the three-step model referred to as Inquiry- and context-based science lesson, (Firgure 1) was statistically significantly higher than the students' science lessons in school ($p < 0.05$), except for item four. This item concerned the link of science to their everyday life. The students' responses in comparing their idea of perfect science lessons and the three-step model only showed a statistical significant difference in item five. This item concerned the usefulness in society. For this item, the model was found useful in society to a higher degree than for their idea of a perfect lesson ($p < 0.05$).

The conclusion was that the students found the lesson with the three-step teaching model more positive than their school science lessons. In other words, close to a perfect science lesson.

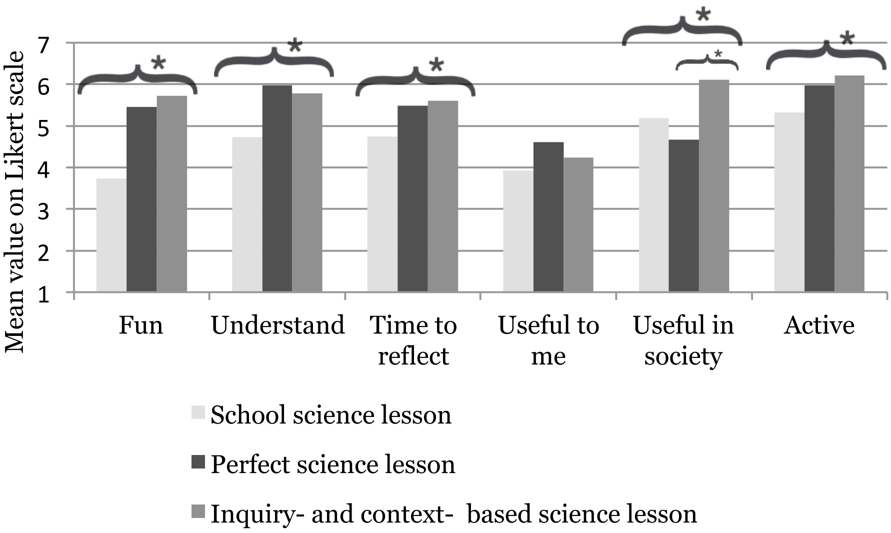

*Figure 1. The comparison of student responses to science lessons in general, an imagined perfect lesson and the inquiry- and context-based science lesson. *Marks statistical significant differences (p< 0.05).*

Summarising main findings from the four papers

The main findings from the five papers can be summarised as follows:

- Primary school teachers found IC-BaSE to be a useful instructional strategy engaging their students and developing their skills in planning inquiries.
- Primary school teachers had not used open inquiries in their teaching before attending a CPD programme; hence, this was new to them.
- Primary school teachers had not used contexts in science teaching before attending a CPD programme.
- Primary school teachers found practical challenges in using IC-BaSE, but presented their own ideas on how to solve these challenges.
- Primary school teachers mainly used IC-BaSE to stimulate their students' interest in science.
- Primary school teachers hardly made any connections between their choice of instructional strategy and knowledge about students' understanding.
- IC-BaSE as instructional strategy to stimulate students' interest in learning science was confirmed to be positive when tried out with secondary school students.

DISCUSSION

In this section, I will discuss the results of the four papers. I will synthesise the discussion both from the perspective of the data (mainly the teachers' voices) and the philosophical and theoretical perspectives (TPD, PCK, instructional strategies and purposes) of earlier research. Finally, conclusions are drawn and suggestions of implications and ideas for future research are given. The discussion starts with a brief reminder of the purpose of my studies.

The purpose of my studies – the gap to fill

The aim of the thesis is to develop an understanding of primary school teachers' knowledge about IC-BaSE from the different perspectives of: what it is, how to use it and why these strategies are needed. The overall research question is:

How do primary school teachers reflect on inquiry- and Context-Based Science Education as a framework for teaching and learning in the primary school classroom?

There were several reasons for choosing this topic. International research has shown that there is a need for PD professional development among primary school teachers (e.g. Anderson et al., 2009; Hackling et al., 2007). Furthermore, Roth (2014) has specifically argued that research on how primary school teachers can develop their knowledge about instructional strategies is needed.

Concurrent with the situation for primary school teachers and the changes in the curriculum, reports on how science education can support and stimulate students' interest in learning science have been discussed and IC-BaSE suggested as part of the solution (e.g. EC, 2007). Hence, a gap to fill was to develop more knowledge about how primary school teachers reflect on the use of IC-BaSE.

Instructional strategies

As I have argued in the introduction, ideas from pragmatism and sociocultural perspectives support the use of IC-BaSE (Dewey, 1038/1998, Peirce, 1878/1992, Vygotskij, 1999). Education based on experience, the use of scientific methods and the need to relate to students' interests were arguments used. These ideas have also been emphasised in recent documents such as the report from the European Commission (2007). In this section, IC-BaSE is one solution to the question how to teach. Primary school teachers' knowledge about what IC-BaSE is and how to use it are the main focus areas.

When the primary school teachers who participated in the CPD programme were introduced to the IC-BaSE model, some parts were new to them. The research question centered on how teachers would respond to the model and if they would find it suitable to use at primary school level. The model had been tried out at secondary school level within the PROFILES project, but I was interested in knowing if it could be useful at primary school level too.

Before attending the CPD programme, the teachers in my study thought that they only used one instructional strategy, inquiry-based, in the form of *NTA*. However, in discussions after the workshops in the programme, it was revealed that several of the teachers also worked ''*stick to the book"*, as they put it. They were not aware of context-based education at all, and different forms of inquiry were not discussed before the programme. In this study, the teachers gained new insights into inquiry-based teaching and saw opportunities to use open inquiry. The teachers reflected on the IC-BaSE model as a way to involve students in the planning process, which was new to them. When Dewey discussed the scientific method (1938/1998), it included the planning of investigations and raising questions. However, the teachers in my studies still wanted to be in charge of the questions asked.

During discussions about the context-based approach, teachers reflected on how science could be taught in a context, rather than as isolated facts, and thereby motivate students' learning. The teachers expressed that all this was possible with the IC-BaSE model, but they still thought that finding contexts adapted to the curriculum and students' interests or everyday life was a challenge. When teachers discussed how to find contexts and questions for inquiries, they agreed that the main responsibility rests with the teacher in order to meet the requirements of the curriculum. However, they also discussed the need to be informed about their students' interests and to include contexts relating to the students' worlds. In other words, the teachers thought that decisions on contextual content should be made by them, but with the help of students. Gilbert (2006) pointed out that the choice of context is crucial and that not every context works. Teachers' ideas of being responsible for the choice of contexts are in line with the arguments made by Veermans, Lallimo and Hakkaraienen (2005). A question to be raised concerning the use of contexts is whether this is possible for everything to be covered in the curriculum. This question was never discussed by the teachers.

When asked how the IC-BaSE model worked in their classes, the teachers were positive. Some of the teachers mentioned how the model particularly engaged low achieving students. This was an interesting reflection since it has been shown by Capps et al. (2012) that inquiry-based science teaching has the potential to engage *all* students. If students are encouraged to plan their own learning activities, they are more likely to get involved in a task (Lin et al., 2009).

The teachers reported that they were faced with some practical challenges when using the IC-BaSE model. However, they also discussed how challenges could be solved. The challenges they discussed were similar to those presented in earlier studies (Anderson, 2002; Jones and Eick, 2007; Kim and Tan, 2011; Luft, 2001; Sormunen et al., 2014). Since solutions to practical problems in IC-BaSE, to my knowledge, have not been discussed to a great extent earlier, it was of interest to explore teachers' own ideas on solutions to practical problems. Their solutions included cooperation between teachers, sharing planned teaching modules, and also using materials and methods they had used before.

The teachers in my studies had their own ideas on how to solve problems of lack of time, which was associated with the handling of materials. The advantage of *NTA* in the teachers' experience was that everything was prepared and available and there was no need to plan and look for material. Thus, the teachers discussed if they could use *NTA* and modify it into IC-BaSE modules. As one of the solutions to the challenge of handling materials, the teachers suggested using boxes from *NTA*.

The teachers' solutions to use the *NTA* boxes could raise some questions. What if they do not have *NTA* boxes for all the units that need to be covered in the curriculum? Could the solution to use *NTA* boxes have the results that teachers were restriced to creating contexts that only would fit the boxes, and perhaps not being able to cover the curriculum? The answers to those questions are: First, *NTA* boxes do not cover all fields in the science curriculum. Second, my experience from work with teachers in the CPD programme, as well from earlier CPD courses, is that this is not a risk. During the CPD programme, the teachers often mentioned the importance of covering the curriculum. If they did not have *NTA* boxes, or other instructional strategies, they would at least *"stick to the book"* to cover the curriculum.

Cooperating and sharing teaching modules were other ideas presented. Challenges discussed regarding the time factor was that when starting something new, it takes time to find new ways of proceeding, both for the teachers and the students. Valdmann et al. (2012) also reported that it takes a long time to prepare teaching modules similar to the three-step model from PROFILES for the first time.

Teachers' discussions did not centre so much on the challenges and solutions for handling materials and big classes, or students working at different paces. Being afraid of losing control in the classroom and how to solve this problem was of greater concern to the teachers. As shown in earlier studies, many teachers fear that they will lose control if using inquiry-based teaching (e.g. Hohenstein and Mannning, 2010; Hutchins and Friedrichsen, 2012). However, after the CPD programme, the teachers seemed to have found strategies to handle this, mainly because of one workshop, in which ways to work with open inquiry without losing control were presented. Some of the teachers were surprised to find how much responsibility their students took, and that they could be trusted to cope with open inquiry. The students were engaged in the tasks and even low achievers showed commitment as mentioned. Valdmann and colleagues (2012) found that teachers generally have relatively little faith in students. To put trust in students, using more student-centred rather than teacher-centred methods, seems to be a challenge for many teachers. However, in this study the teachers experienced positive effects when they trusted the students and used student-centred activities. It was shown that when teachers dared to put trust in their students, it did not necessarily end in chaos. This was also found in a recent study by Svendsen (2015).

Summarising discussion about instructional strategies

The primary school teachers developed their knowledge of inquiry to include open inquiry and having students plan inquires. This is in line with the intentions of inquiry (e.g. Dewey 1938/1998; Lin et al., 2009; NGSS, 2013). The teachers in my studies also developed their knowledge about the use of contexts, which was a novelty to them. The use of contexts is an idea supported by earlier research from philosophical and theoretical perspectives (e.g. Bennet et al., 2007; Dewey, 1938/1998; Gilbert, 2006; Vygostkij, 1999). However, the practical challenges when using IC-BaSE were of great concern to the teachers. The challenges they found were not new, but the teachers presented their own ideas to solve the challenges, which I have not seen in earlier research.

Purposes of using IC-BaSE as instructional strategy

Previous studies have shown a need for teachers to develop their PCK (e.g. Shulman, 1986, 1987; Nilsson, 2008a, 2008b, 2014). Even though I expected that the CPD programme, introducing teachers to a new teaching model, would lead to many discussions related to PCK, and especially instructional strategies, it also inspired discussions of other components of PCK. Still, neither before, nor after the CPD programme did the teachers discuss when or why to choose a certain instructional strategy. There may be several reasons for this. The teachers only talked about *NTA* as an instructional strategy before the workshops, probably because they did not know of other strategies, and therefore could not reflect on the purposes of choosing one way or another. After the workshops, they discussed how they could use the new strategies as a complement, but once again without giving arguments for when or why. Another reason could be that the CPD programme focused on introducing the IC-BaSE model from PROFILES as an instructional strategy, and the practical aspects of using the model were of major interest to the teachers. It could also be argued that the instructions were not clear enough to involve the teachers in reflections on the purposes of using the IC-BaSE model.

Since the teachers had discussions in groups without researchers participating, the discussions did not always cover what was aimed for. Interviews or researchers participating in the group discussions could have solved this problem. As mentioned earlier, teachers discussed different issues of PCK but did not explain further because the focus was on instructional strategies. Although they did address other PCK issues (mainly assessment) during the discussions, the connection between choice of strategies and students' understanding were never mentioned. All PCK aspects are important, and as emphasised by Park and Chen (2012) the connections between the different aspects of PCK need to be strengthened among teachers if the quality of PCK is to improve. Thus, teachers also need to relate to the purposes of choosing certain instructional strategies, on the basis of their knowledge about students' learning and the content to be learnt. The results of my studies were similar to studies made in Denmark (Nielsen, 2012). Nielsen found that teachers in her studies mainly focused on hands-on activities without awareness of what the students were supposed to learn. The teachers' reflections focused on the students' engagement and motivation rather than on the students' learning.

The primary school teachers in my studies reported that the use of IC-BaSE engaged their students and the teachers' reasons for using it mostly seemed to be that students should have fun. They argued that students enjoyed the practical work, but one teacher also mentioned that some of her students in grade six seemed to be fed up with the *NTA* boxes. However, after using the IC-BaSE model, this was not the case. She did not have any explicit explanations as to why. Could it be that the students were planned inquires on their own, or that they knew the purposes of the activities?

During the CPD programme provided for primary school teachers, they thought that their students often did not know why they are doing inquiries. This suggestion generated a new research question. What about the teachers then? Are they always aware of why they are using inquiry or contexts in their teaching? Abell and McDonald (2006) described how primary school teachers have strong beliefs in activity driven science and the use of hands-on inquires without focusing on what students are supposed to learn from the activities. They referred to this as "activitymania." Similarly, Magnusson et al. (1999) observed that teachers might have an activity-driven orientation where the goal is to have active students involved in hands-on experience, where activities are used for verification or discovery. Magnusson and colleagues (1999) further pointed to the importance of teachers understanding what they do:

> The chosen activities may not be conceptually coherent if teachers do not understand the purpose of particular activities and as a consequence omit or inappropriately modify critical aspects of them (p. 101).

I do not claim that the teachers in my studies had this orientation, but the purposes of choosing inquiry or IC-BaSE as instructional strategies turned out to be of a special interest of mine and particularly investigated in Paper III.

Lindahl (2003) argued that students lose interest in science if they do not know the purpose of performing an inquiry, or if they cannot relate to a context. Dewey has often been cited in the context of *learning by doing*. Indeed, he coined the expression in one of his books (Dewey & Dewey, 1915/1962), but learning by doing, or using inquiry is much more than just doing. It is also important to know the purposes of the doing. When discussing the importance of teachers' knowing the purposes of activities, Wickman (2014) argued that they needed to be clear with their students about the purposes. His arguments are based on Dewey (1938/1998) and his idea of aims as *ends-in-view*. Wickman argued that the majority of students believe that the purpose of the teaching they encounter is mostly to learn how to perform inquiries, the practical aspects, the doing. However, the question is whether the teachers in my studies also are somehow stuck in the "doing", even though they expressed that they had other intentions with the teaching. When the teachers discussed their purpose of choosing IC-BaSE, the argument was that this engaged their students. They did not argue that their choice was made to stimulate and facilitate the students' understanding. This argument was only used by one of the teachers, who used drama as a complement to her teaching.

As mentioned before, previous studies have shown how teachers using inquiry have focused on their students having fun and not on the learning of content (Berg, Löfgren, & Eriksson, 2012; Hart, Mulhall, Berry, Loughran, & Gunstone, 2000). However, I believe that the teachers participating in the study presented in Paper III, even though they did not reach a complete match between the purpose of the teaching and their choice of instructional strategies, have started to reflect on their purposes and how they communicate with their students. I agree with other researchers (e.g. Harrison et al., 2008; Nilsson, 2009; Schön, 1983; Simoncini et al., 2014; Prestridge, 2014; Rauch, 2010) that for a teacher to develop PCK, it is necessary to reflect upon the teaching practice.

In the study presented in Paper III, a modified model was used, which was originally developed by Marton and Pang (2006) and Marton and Ling (2007). The results were analysed as the teachers *intended* objectives of teaching, the *enacted* teaching, how the students *experienced* the objectives of the teaching and finally, the relation between intended, enacted and experienced objectives of teaching. Not until the teachers encountered the students' experiences did they realise that there was a gap between their objectives and the students' experienced objectives of the teaching. Both the students and the teachers had *ends-in-view* (Dewey, 1938/2004). However, if the teachers in this case want their students to experience what they intend, they probably need to make some changes in order to achieve all of their objectives. This was also a reflection the teachers made in the final interview during the study.

In Paper III, the teachers' purpose of choosing IC-BaSE as instructional strategy was to engage their students, and involve them in the planning process. This purpose was successful. However, the purpose, or intended learning objective, was also that the students should learn some content about water during the activity using IC-BaSE. The students never realised that this was a purpose, but thought that they were supposed to develop their skills in inquiry. To develop skills in doing inquiry is not wrong and it is also part of the goals in the curriculum.

The students' experiences were not really a surprise to me, as bystander, observing the instructions given. In the hand-out to the students, it was stated that they were supposed to develop their skills in doing inquiry. When the teachers finally realised that their intended purposes related to the content to be learnt did not match the students' experience, they discussed how they needed to change their practice if they wanted to fulfil that particular purpose. Hence, students' responses may have an impact on teachers as argued by Park and Oliver (2008).

Students' perspectives are investigated in Paper IV to find out how they would respond to the IC-BaSE three-step model from PROFILES. The context was a crime technology case. The results showed that the students were motivated by a context, which was not part of their everyday life, but they found it useful in society and this was obviously enough to stimulate their interest. Again, the choice of context is important, and the purpose for the students was clear, they had an *end-in-view*, to solve a crime case. The purpose of using the model with the students was to stimulate their interest in learning science, which it did. This was in line with earlier studies that students' interest in science learning can be increased through IC-BaSE (e.g. Gutwil-Wise, 2001; Kennedy, 2013; Parchmann et al., 2006).

From the perspective of inquiry, Crawford (2007) argued that the purposes of using this instructional strategy are to learn how to do inquiry, to understand about inquiry and to learn concepts through inquiry. The first reason was perhaps in focus for the teachers in my studies, even though they discussed the importance of conforming to the curriculum and reaching goals of learning about specific content (e.g. the water cycle).

Maybe the arguments for using IC-BaSE to stimulate students' interest in learning science have superseded the other purposes. Sevian and Talanquer (2014) expressed this danger related to the use of context-based approaches. Based on my studies, I believe that there is a need also to emphasise the use of these instructional strategies in terms of other purposes than just stimulating students' interest in learning science. In my opinion there is a need to investigate and emphasise how the strategies are useful in the perspective of learning as well. The teachers participating in the study mentioned that their students had learnt how to plan investigations when they were using an IC-BaSE model. This is a learning objective and can be one of the reasons for using this strategy. However, one of the teachers also combined her instructional strategies and added drama to the IC-BaSE model. In my opinion, this was a good choice since IC-BaSE is not the one and only way. It is necessary to use a range of strategies since students learn in different ways. The most important issue of my concern is that the use of inquiry activities must move from "activity-mania" (Abell & McDonald, 2006) and "activities that work" (Appleton & Kindt, 2002; Furtak & Alonzo, 2010) to being a purposive strategic choice: from only "doing" to also "knowing", including why and how to use it. To have a purpose in which students are supposed to enjoy science education is far from wrong, but the learning objectives need to be emphasised even more

Summarising purposes of using IC-BaSE

Even though the purpose of using IC-BaSE was not specifically investigated in Paper I, it seemed as the twelve teachers in this study had an overall purpose of using IC-BaSE to stimulate students' interest.

Two teachers participated in the study about purposes of using IC-BaSE presented in Paper III. These teachers also mainly discussed the use of IC-BaSE in terms of students having fun, with less awareness of what students were supposed to learn from the activities. However, when exposed to how students experienced purposes in some science lessons with IC-BaSE, the teachers became more aware of their purposes and how they communicated them to the students. One teacher had already added another instructional strategy in her teaching to support her students' understanding of the water cycle. So, at least one teacher was thinking of the aspects of supporting learning and adapting choice of instructional strategy accordingly.

Reflection and experiences

The overall research question in this thesis is how primary school teachers *reflect* on Inquiry- and Context-Based Science Education as a framework for teaching and learning in the primary school classroom? The word *reflect* is italicised here to emphasise this part of the studies. However, the reflections were probably affected by several factors, such as the teachers' experiences.

Dewey (1938/1998) argued that reflection demands community and the diverse perspectives on practice that community brings. Vygotskij (1999) and Rodgers (2002) believed that gathering different perspectives is a necessary step and that diverse points of views are important to broaden instead of narrow the conversation. I found that teachers participating in my studies were not of different views. Even though they came from separate schools, and the schools were situated in areas with different socioeconomic backgrounds, the teachers reflected in similar ways. Their experiences of science teaching were the same in the sense of their use of instructional strategies (working with *NTA* boxes). On the other hand, the fact that the teachers were united in their discussions and reflections does not necessarily need to be a disadvantage from my point of view. Sharing similar experiences could also strengthen the teachers.

Knowing that the teachers participating in my studies had experiences of *NTA*, I also knew they had at least some education in teaching science and some SMK. However, Kind (2009) claimed that it is not enough to have SMK even though there are organisations that expect those who have more SMK to be better teachers. She referred to the following statement of the Royal Society of Chemistry in the UK:

> The best teachers are those who have a specialists' subject knowledge and a real passion and enthusiasm for the subject they teach (RSC, 2004, quoted in Kind, 2009).

In contrast, Kind (2009) argued that even if a teacher has an academic degree in a subject, it is not a guarantee that the teacher will teach effectively. Good teaching skills are also necessary and according to her, this is what PCK is all about. PCK is developed over time and through experience, but experience is not enough. Teachers' reflection on their teaching is also important in developing PCK (Nilsson, 2009). The teachers participating in my studies had several years of experience, but they gained new understanding when discussing and reflecting on their practice. Thus, to provide teachers with the opportunities for reflection is important in TPD (e.g. Harrison et al., 2008; Nilsson, 2009; Schneider & Plasman, 2011; Schön, 1983). Both in their group discussions, and individual portfolios, which were used as data collection in Papers I and II, the teachers emphasised how fruitful the reflections had been to them. The teachers argued how they had appreciated listening to each other, and also to reflecting on their own practice. Presented below are two examples from the portfolios:

> When we were sitting in the groups discussing, I developed a wider and deeper understanding of how I think about science teaching. To listen to the thoughts from others on science teaching made it possible for me to reflect on my own practice. I think this will affect my teaching in a positive way (Teacher 4).

> I cannot really put it into words, but it feels as if I am developing, I start to reflect on the teaching with new eyes. … And I think it is interesting to meet others and discuss how they work, exchange experiences. This we seldom do. It also feels good that others may feel uncertainty and that it is possible to learn and develop the whole time (Teacher 3).

The teachers claimed that reflections with colleagues led to development. Yet, they found it difficult to explain how they had developed. Maybe it is hard to explain your own development when you still are in the middle of a process. Additionally, perhaps the teachers needed more time and distance to the CPD programme to be able to explain how the reflections actually had contributed to their development.

The primary school teachers who participated in the studies presented in Papers I–III had both years of experience teaching in science, but also at least one year of science education. However, despite education and years of experience, they argued that without *NTA* boxes they did not know how to teach science and thus, found the CPD programme useful in meeting their needs of more instructional strategies. The teachers' need for more PCK, at least in terms of more knowledge about instructional strategies was clear. Still, knowledge about instructional strategies is only one part of PCK. Since the discussions about choices of strategies were hardly ever connected to issues about students' understanding, this part of PCK could also be a need among primary school teachers. To a small extent, the teachers mentioned lack of SMK, and as earlier argued there is a relation between SMK and PCK.

Issues of teachers' lack of SMK and how this also affects their PCK have been addressed in earlier research (Appleton, 2006; Halim & Meerah, 2002; Hasweh, 1987; Käpylä et al., 2009; Nilsson, 2008a, 2009; Van Driel et al., 1998). The teachers participating in my studies, even though they were primary school teachers, had adequate education in teaching science. As already mentioned, some of the teachers had at least one year of education in science subjects. This can be considered satisfactory for a teacher in primary school. Therefore, the issue of SMK was not considered to be the most important factor in my research, even though it is considered as connected to PCK (e.g. Grossman, 1990; Marks, 1990; Shulman, 1986, 1987.) Still, occasionally some of them mentioned the lack of SMK and how this also affected the way they taught. In my opinion, a teacher can never have too much SMK, but at the same time, it should not be expected that a primary school teacher is an expert in science the same way as a secondary school teacher is.

Summarising the role of reflection and experiences,

The teachers in my studies did not show conflicting opinions during their discussions; on the contrary, they were quite united in their opinions and experiences. From pragmatic and sociocultural perspectives, diverse views could broaden the perspective. Sharing similar experiences, the discussions between the teachers maybe did not broaden the teachers' perspectives. Still, confirmation from colleagues may have strengthened them. Even though the teachers had education in teaching science and years of experiences, their need for more PCK and maybe also SMK can still be argued to exist. I would express it such as TPD is a life-long journey.

The participating teachers´ professional development

In this section I reflect on the PD of the teachers who participated in my studies. In my view they have taken some steps on their professional journey as teachers in science. First, they worked for some years using the teaching material *NTA*. During this time, they developed their practical skills in using the prepared boxes with all the equipment necessary to perform inquiries with their students. By using this material, the teachers gained confidence in teaching science. However, without this material the teachers felt insecure and were not sure of how to teach science. When they worked with *NTA,* there was no need to plan investigations either for them or their students. The students were not stimulated to ask their own questions, as these were already posed in the material. The "doing" of inquiries was the important thing. Still, skills were developed both among teachers and students. This is not to say that the *NTA* model is deficient; on the contrary, it has been very popular among the teachers, and they reported that many of their students have enjoyed working with the *NTA* material.

When the IC-BaSE three-step teaching model of the PROFILES project was introduced to the teachers, some parts were new to the teachers and their students, and new steps were taken. For the first time, students now planned their own inquires, based on their earlier knowledge of working with *NTA*, checking variables and making hypothesis. Nonetheless, the teachers wanted to have some control of the questions to be investigated in order to be able to conform to the curriculum. Another novelty was the use of contexts and relating to students' interests or everyday lives. Both the planning of investigations and the use of contexts were considered to be positive experiences by the teachers, and they also reported that their students were really engaged, even students who often were low achievers in science. The teachers also realised that inquiries could have different forms, such as being structured, guided or open.

Another step taken by the teachers during the project was that they developed their own ideas on how to deal with the challenges of IC-BaSE. This is interesting because teachers themselves presented the ideas and because they tried to figure out how they could overcome the challenges instead of being hindered from using these instructional strategies. I believe that the students' responses had an impact and stimulated the teachers to continue using these strategies.

In one of my studies, the teachers showed how they started to develop an understanding of the importance of knowing and communicating the purposes of the teaching activities, although this insight was seldom related to students' understanding. The purpose of stimulating students' interest and developing their skills in "doing" inquiry was the primary focus. This is a useful and commendable purpose. However, there is reason to believe that even primary school teachers need to make their choices of instructional strategies clear in relation to the students' understanding.

Reflections on the research process

The research presented in this thesis is mainly based on primary teachers and their experiences. The research was performed together with the teachers and part of their teaching practice. In this section I discuss issues of the research process, problematising whether the research could have taken other directions if I had made other choices.

Perhaps too much focus was on the IC-BaSE model and the practical aspects of using it in some of my studies. I did not have a great deal of experience in supporting and challenging the teachers in their reflections and maybe a more experienced researcher could have affected the teachers in another way. Thus, their reflections could have been different. Yet, the teachers participating in my studies developed when they were discussing and reflecting upon their practice. Dewey, Vygostskij and others have emphasised the importance of reflection and, as I have argued, teaching, or learning, is not only a matter of "doing". I think the primary school teachers in my studies have progressed further. They are not merely stuck in "activitymania" (Abell & McDonald, 2006) or "activities that work" (Appleton & Kindt, 2002; Furtak & Alonzo, 2010).

If my studies had involved primary school teachers with no experience of using inquiry-based teaching, or with less, or no education in science, the results would probably have been different. The teachers in my studies were also experienced, which probably influenced the results. However, as I have argued before, I wanted to investigate primary school teachers' reflections when they have taken some steps in their path as science teachers with less risk of ending up with results only being focussing on lack of SMK.

Finally, sociocultural aspects have probably affected the results in the resepect to the teachers' experiences and the context they come from. If the studies had been performed in another country and culture, the results could have been different. The analysis of data and my voice as a researcher are also affected by the sociocultural background I have. The traditions of research in science education in Sweden and discussions I have with researchers in my environment influence the way I think. Thus, as Wertsch (1991) argued:

> … it is both difficult and meaningless to isolate various aspects of mental processes for separate analysis…The milieu in which the actions are taken place is interacting with the mental processes (p.14)

Conclusion

The developed picture of the answer to the overall research question of how teachers reflect on IC-BaSE as a framework for science teaching and learning in the primary school classroom is as follows:

The teachers found that IC-BaSE is a good complement to their instructional strategies in science teaching. They argued that it engaged their students and stimulated their interest in learning science. It also introduced the teachers to the possibility of performing open inquiry at primary school level, without ending up in chaos. However, the teachers still wanted to be responsible for the questions to be asked even though the curriculum (Lgr 11) mentions that the students are supposed to pose the questions. The reason for the teachers wanting to be in charge of the questions was that they were afraid of not fulfilling the curricular objectives otherwise.

Teachers found that the use of contexts was effective in order to engage their students, but also that it was difficult to find appropriate and good contexts relating both to the curriculum and students' everyday life. According to the teachers, the practical challenges of using IC-BaSE could be solved mainly through cooperation between teachers and the use of materials they already had access to.

The purpose of using IC-BaSE was not fully clear to the teachers. Thus, further development of PCK, with an emphasis on discussing choices of instructional strategies in relation to students' learning and understanding, is still needed among primary school teachers.

Implications for teaching

The main studies in my research are based on the reflections of primary school teachers, who all had some education in teaching science, and some experience of inquiry-based science education. How can my studies have an impact? Since I know that many primary school teachers in Sweden have the same background, I believe that the studies can have an impact. Primary teachers can develop their knowledge about instructional strategies and as a result, their teaching practice.

Van Driel et al. (2014) have claimed that long-term interventions in combination with follow-up support appear to be important ways of gaining sustainable changes. For me, it was important to make the teachers try IC-BaSE during the projects. The reason for this is that I believe that the effect of students' positive responses can affect and motivate teachers to continue using the strategies. Since my results showed that especially the students' experiences of the teaching had an impact on the teachers' reflections on their practice, this is a tool I would especially recommend.

Another important aspect is that if PCK is to be useful in science teacher education we need to know how teachers develop. My studies have shown that both teachers' reflections and their experiences of teaching and relating to the students' responses are important in this process. I also believe it is important to include all aspects of PCK in teacher education, even if all were not included in my studies. Berry, Loughran and Van Driel (2008) have argued that the demands of time, curricula and student achievement tend to create a focus more on "doing teaching" rather than explicating the associated pedagogical reasoning. Appleton (2006) among others, also claimed that primary school teachers have been focused on "activities that work". In my view, primary school teachers have been focused on "doing" experiments, but my studies have aimed to stimulate and investigate how primary school teachers could move away from only be "doing", to also knowing *why* they are doing the activities and *how* to do them.

I also recommend TPD programmes to include discussions of practical issues in teaching, particularly when enhancing inquiry-based teaching to prepare students for the reality of lacking time, handling big classes and collecting teaching materials. There is clearly a need to include these aspects in teacher education programmes if we want teachers to overcome the challenges, not being afraid of losing control and to use IC-BaSE, even if this requires some efforts.

The teachers in my studies did develop their PCK, but there are still more steps to be taken. It is not only a matter of embracing the instructional strategies “on the agenda”, such as inquiry or context-based approaches, but also to use them for a reason and connect to the students’ learning process. Thus, teachers should not be satisfied with only stimulating students’ interest when “doing” science. Of course, we still need to stimulate students’ interest, but we should not forget the learning part. The purpose of using inquiry-based methods needs to be considered and made explicit.

There are many ways to teach specific science content. Since the results of my studies, as well as those of others have shown that IC-BaSE has positive effects on students, I hope that teachers will include IC-BaSE as one of their instructional strategies. However, while bearing in mind this is not the one and only strategy available.

Future research

If an innovation such as IC-BaSE is to be implemented successfully as an instructional strategy, it must be a natural part of the teachers' repertoire of teaching, and they must come to use the "new" practice automatically. Therefore, it would be interesting to revisit the teachers in a few years to find out if they are still using IC-BaSE.

The effect of students' responses to teaching in science and the effect on TPD could be of interest to investigate even more, as such studies at primary school level are scarce.

Research investigating primary school teachers' choices of instructional strategies in relation to students understanding can be further explored. It does not necessary need to connect to IC-BaSE specifically, but to other strategies as well. Lemke (2001) claimed that:

> A sociocultural perspective tells us that we should be doing research to discover the best ways to integrate science teaching to different needs (p. 306).

My studies were performed in a Swedish context. To explore how teachers reflect on IC-BaSE as a framework for teaching and learning in primary school classrooms it would be of interest to compare with similar studies in other countries. Hence, even more aspects of sociocultural aspects could be included.

Finally, I would like to refer to Dewey (1938/1998) again and his view that the scientific method of raising questions, making hypothesis, testing, observing and reflecting upon what happened is a way of developing the teaching of most subjects. Furthermore, he did not see inquiry only as a way of gaining knowledge, but also as a way of learning how to solve problems. In preparing students for life, we therefore need more knowledge of how IC-BaSE can be developed.

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From doing to learning

Inquiry- and Context-Based Science Education (IC-BaSE) have been suggested as useful, stimulating students' interests in learning science. The aim of this thesis is to develop an understanding of primary school teachers' knowledge of IC-BaSE from different perspectives: what it is, how to use it and why these strategies are used.

The results are discussed with reference to theories mainly based on pragmatism, but also from a sociocultural perspective. The findings show that primary school teachers found IC-BaSE useful in the primary school classroom, as it engaged their students and developed their skills in planning inquiries. Students' experiences of IC-BaSE are included and show positive responses to the use of these strategies. However, when teachers were informed about their students' responses, they became more aware of the importance of informing the students about the purposes of the activities, and to reflect on why they themselves choose IC-BaSE as instructional strategies.

The findings presented show that teachers need to move forward, not only be "doing", but also knowing *why* they are doing the activities and *how* to do them. Students' experiences can contribute to this awareness among teachers and develop the teaching practice.

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