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Teachers' Views on Inquiry-Based Learning in Science

A Case Study from an International School

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ABSTRACT

This thesis presents a study of teachers' perspectives on inquiry-oriented approaches and how they conceptualize them. Five teachers from an international school were interviewed. They were asked to describe how they interpret inquiry-based teaching, and to give examples of their own teaching practices in line with inquiry-oriented teaching. Additionally, the teachers were asked for the constraints they face in implementing an inquiry lesson. The results from the inductive analysis show that teachers considered student autonomy as most prominent in their perception of inquiry-based approaches to science teaching. Nevertheless, their examples revealed that they consider content knowledge of curriculum, and how this connects to the real world as equally important as the student autonomy. Implementation of inquiry-based learning in classrooms presents a number of significant challenges. However, case and cross case comparisons, revealed seven main constraints that impacted their enactment of inquiry-based instruction namely: curriculum, time management, students' prior knowledge, students' motivation, physical size of the classroom and the limited resources, good search engine and designing authentic assessment. This study also unveils the teacher’s personal suggestions that may support them in inquiry-based teaching approaches, collaborative planning, and professional development course and action research.

PREFACE

This is a written report of a Master Thesis for the Masters' of Physics Didactics program in the Department of Physics at the Norwegian University of Science and Technology (NTNU). The study entailed a qualitative analysis with an important empirical part in the form of interviews with the teachers within the field of science education. The case study was conducted at the Trondheim International School, Trondheim, Norway during the period between November 2011 and September 2012.

After coming to Norway, I had the opportunity to work in the international school where inquiry-based approaches form a part of the school policy. The inquiry-based learning was new and different from how I taught in India. This difference not only fascinated me, but also seeded the thought to explore inquiry-based learning. Moreover, this research project is a step towards further understanding the new format of inquiry-based learning method.

This study process has been a great learning experience for me as it has provided me with a very valuable international experience of working together with people from different cultural backgrounds. It also enhanced my knowledge of the technique of inquiry-based learning, which was an additional benefit for my teaching career.

It has been a great experience to work on such an exciting problem. It is a pleasant aspect that now I have the opportunity to express my gratitude for all of them who made this journey easier. I wish to acknowledge and thank a number of people who supported me in completing this study. I am very grateful to Principal Ken Sell of the Trondheim International School for his support and kind approval of the data to be gathered from the school. I also thank all teachers who provided me with the necessary information to conduct the research. I remain indebted to their valuable feedback and discussion sessions, hospitality, professionalism, friendship, and their consent to participate in this study. It would have been impossible to complete this project without them.

I would like to take this opportunity to thank my supervisor Berit Bungum in Skolelaboratoriet at the Norwegian University of Science and Technology (NTNU) for her professional guidance and mentorship for this study. She made the research problem easier for me with her perceptiveness, inspiration, and great efforts to explain things clearly and simply. I

extend my gratefulness to her for her stimulating discussions and suggestions during various stages of the work. I am also indebted to Jon Andreas Støvneng at the Department of Physics, NTNU who acted as my second supervisor. His support motivated me to complete this study.

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CHAPTER 1. INTRODUCTION

Teachers are the most important factor for realizing intentions in education. Previous research has noted that teacher perceptions play a key role in reaching the goal of learning through scientific inquiry and the research supports the idea that teachers are crucial agents in educational reform and that teachers' beliefs are precursors to change (Mansour, 2010). This thesis investigates how teachers interpret the aims and contents of inquiry-based teaching, the constraints and challenges they meet in realizing these aims and the kind of support they need. Data collection was undertaken by means of semi- structured interviews and analyzed in the light of current perspectives on science education and value of inquiry.

The present study has been presented in two parts for better understanding the teachers' views on the notion of "inquiry" in science education.

Part one: It is a non-empirical study, where I have reviewed perspectives and approaches to inquiry-based learning based on recent literature. The aim was to explore ways in which various views of learning, support inquiry approaches in science teaching. This formulates the first research question of the present study.

1. In what ways do various views of learning support inquiry approaches in science teaching?

Part two: It is an empirical part and a case study. The objective was to find out teachers' perception on inquiry-based learning and factors affecting teachers' motivation for inquiry-based learning with the help of the following three research questions.

2. What are the teachers' personal views on the content and aims of inquiry-based science teaching?
3. How do these views relate to what they consider to be inquiry-oriented approaches from their own teaching practice?
4. What are the constraints teachers faces in designing or executing the inquiry lesson?

The importance of this study includes trying to understand the challenges and constraints associated with teaching science as inquiry situated in the realm of ordinary school science classrooms. The goal is to better understand the nature of teachers' beliefs about science

teaching and learning and its links to practice. The efficacy of reform efforts rests largely with teachers; their feedback needs to be included in the design and implementation of inquiry-based curriculum. This will be helpful in designing a professional development program which will coincide with teacher's goals and expectations. Ultimately, this study aims to help design various professional development approaches that will increase inquiry-based teaching of science in the classrooms.

The main results from the empirical study were presented in the 10th Conference of the European Science Education Research Association (ESERA) and the proceeding paper is included in appendix 2.The results was also published as a chapter in the book "The Teacher as Researcher: Case studies in educational research" (Panjwani & Bungum, 2014).

CHAPTER 2. INQUIRY-BASED LEARNING: THEORETICAL BACKGROUND

In this modern era, the world needs increasing numbers of science and technology professionals to carry the nations into a technologically driven future. The decline in student enrollments in science and technical courses has alarmed the world (Osborne et al, 2010; Rocards report, 2007). The innovative approach called inquiry-based learning has shown a positive effect on student motivation, enthusiasm and attitudes towards both science and school science learning (Gibson & Chase, 2002). As per Nuffield Foundation's report on Science Education, a reversal of school science-teaching pedagogy mainly deductive to inquiry-based methods may increase students' interest and attainment levels while at the same time stimulating teacher motivation. Many studies conducted on middle and high school students have concluded that inquiry-based science activities have positive effects on students' achievement in science in terms of cognitive development, laboratory skills, science process skills, and understanding of science knowledge as a whole (Gibson & Chase, 2002). Besides, as per Rocard reports 2007, "Inquiry-based science education (IBSE) has proved its efficacy at both primary and secondary levels in increasing children's and students' interest and attainment levels while at the same time stimulating teacher motivation. IBSE is effective with all kinds of students ranging from the weakest to the most able and is fully compatible with the ambition of excellence". The science education community mostly agrees that pedagogical practices based on inquiry-based methods are more effective. The reality of classroom practice is that in the majority of European countries, these methods are not being implemented to the expected levels (Rocard reports, 2007).

To promote this inquiry approach various projects such as Sinus Project in Germany, Pollen Project in 12 cities of the European Union, Mind the Gap with seven European countries and the S-Team (Science-Teacher Education Advanced Methods) project in 15 European countries are being carried out. Despite this widespread interest in inquiry-based learning approach, the matter of the fact is that learning theories that are used to support the inquiry science class are still not defined. Therefore, the present study aims to find a link between learning theory and inquiry-based learning based approach with a literature review, in Chapter 3 - Non Empirical Part of the study.

The study of teachers' beliefs forms a part of the process of understanding how teachers conceptualize their work which in turn is important to the understanding of teachers' practices and their decisions in the classroom. Additionally, there are many mediating factors that serve to influence a teacher's ability to play out his or her beliefs in practice. Teachers may hold beliefs that inquiry-based approaches support student thinking and conceptual understanding of science, but other beliefs, related to the transmission of knowledge and coverage of content, may be in conflict (Bryan, 2003; Bryan and Abell, 1999). As noted by Keys and Bryan (2001), we have little knowledge of teachers' views about the goals and purposes of the inquiry. The state of affairs is that many teachers appear to have difficulty creating classroom environments that are inquiry-based that support their students in developing informed views of scientific inquiry and the nature of science. Besides, Gyllempalm et al. (2010) cited "Almost 20 years ago, Debeor (1991) concluded that teachers continue to be unclear about the meaning of inquiry and confuse the idea of inquiry as a teaching strategy with inquiry as learning outcome". Moreover, studies by Flick and Lederman (2004) indicate that a teacher's understanding of inquiry, including its many pedagogical and curricular nuances, is still problematic. Several researchers have suggested that professional development programs designed to help teachers implement inquiry-oriented instruction are minimally effective, in part because teachers filter what they learn through their existing beliefs (Stipek et al. 2001). The teachers' views on learning and teaching will shape their interpretations of curricular and instructional approaches (Crawford, 2007). Bryan (2003) performed a case study of an elementary teacher and he concluded that, teachers' beliefs may constrain their ability to enact inquiry-based instruction. Mansour's (2010) findings indicate that unless curriculum developers take account of teachers' beliefs and knowledge and the sociocultural factors, the inquiry-based learning is unlikely to be implemented according to their intended plan.

It is well known that imposed reforms run the risk of failing if teachers do not accept or understand innovation (Pintó, 2005). For any science education reforms, teachers' beliefs are vital. It is important to understand a teacher's beliefs, and in what ways these beliefs are enacted in actual teaching practice (Bryan, 2003). So for implementation of any successful educational reforms, we need to consider the teachers' views. Therefore, the aim of the second part of the present study is to explore the teacher's views on inquiry-based approaches to science teaching and to understand how these views are realized in concrete teaching practice.

Inquiry-Based Learning

Inquiry-based learning (IBL) is “learners being active” - a student centered pedagogy, which is different from memorizing facts in traditional approaches. In inquiry-based learning, students explore and build new knowledge based on their previous knowledge with the support of teachers, technology and peers. Earl and Katz (2002) call it “inquiry habit of mind” and define it as: “we consider inquiry to be a habit of mind; it is a dynamic, iterative process with feedback loops that organize ideas towards clearer directions and decisions. By drawing on information in this way, inquirers move closer and closer to understanding the phenomenon of interest”. According to them, people with an inquiry habit of mind “develop a mind-set of being in charge of their own destiny and creating or locating the knowledge that will be useful for them along the way". This quality of mind is very important for all human beings. Even for Douglas Llewellyn (Corwin Press, 2002) inquiry is the science, art, and spirit of imagination. He defines inquiry as "the scientific process of active exploration by which we use critical, logical, and creative thinking skills to raise and engage in questions of personal interests". Driven by our curiosity and wonder of observed phenomena, inquiry investigations usually involve:

• Generating a question or problem to be solved
• Choosing a course of action and carrying out the procedures of investigation
• Gathering and recording data through observation and instrumentation to draw appropriate conclusions

As we communicate and share our explanations, inquiry helps us connect our prior understanding to new experiences, modify and accommodate our previously held beliefs and conceptual models, and construct new knowledge. In constructing newly formed knowledge, students are generally cycled back into the processes and pathways of inquiry with new questions and discrepancies to investigate. Inquiry-based learning emphasizes the personal interest in the process of acquisition of new knowledge based on prior knowledge of cognitive development. This personal interest aspect of inquiry-based learning can not only make the students motivated but can also increases the popularity of inquiry-based learning in science education. Besides, according to Tytler (2002b), there are eight components of effective science teaching and learning: 1) encourage students to express their ideas, 2) challenge students to develop meaningful understanding, 3) create correlation between science and their lives, 4) apply varied strategies to monitor students’ learning, 5) apply varied and continuous

assessment, 6) represent science in different aspects, 7) link classroom programs with the community, and 8) apply technology for effectiveness. These eight components are most likely to apply to the class by inquiry-based approaches.

An inquiry can have broad and narrow conceptions, depending on personal beliefs and goals of the teachers and the researchers. In this thesis, two definitions were chosen as a common basis for discussion, the first given in The National Research Council (1996) and the other one given by Linn et al. (2004). The National Research Council explains an inquiry as a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (National Research Council, 1996). It considers the student to be more like a scientist. Whereas in the definition given by Linn et al. (2004) "inquiry is the intention of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning, researching, searching for, constructing models, debating peers, and forming coherent arguments". They included the very important aspect of inquiry-based learning; cooperative learning as "debating peers and forming coherent arguments". In the following section, we have identified and elaborated on the six characteristics of inquiry-based learning on a review of the literature.

Characteristics of inquiry-based learning

1. Cognitive Development

Inquiry-based learning often aims for cognitive development. In other words, it can be said that inquiry-based learning enhances cognitive development in science education. According to Nuangchalerm and Themmasena (2009), inquiry-based learning activities promote cognitive and analytical thinking, and learning satisfaction in students. In cognitive development, previous knowledge, motivation and interest play a significant role. As explained in the inquiry definition by National Research Council, 1996, "examining books and other sources of information to see what is already known in light of experimental evidence", prior knowledge is considered vital for a new experiment. To support it, for example, in a class with students of the same age group, all students perform differently. This

may be due to the fact that all students are unique and have different interests and prior knowledge. Considering students as unique with different areas of interest in inquiry-based learning, various methods of instruction and assessment are used. As even mentioned by Linn et al. (2004), inquiry is defined as “distinguishing alternatives” which acknowledge student diversity and encourage the students to participate with an opportunity to make choices based on personal interests.

2. Social and cultural context

“Learning is not the lonely act of an individual, even when it is undertaken alone. It is the matter of being initiated into the practices of a community, of moving from legitimate peripheral participation to centripetal participation in the actions of a learning community” (Lave and Wenger, 1991). The language cannot be separated from the learning environment. It is said that “learning is context dependent”. According to Leach and Scott (2002), science teaching entails a kind of “public performance” on the social plane of the classroom. The classroom is a very good example where students interact with each other and the environment and learn how to “communicate the results” (National Research Council, 1996). Language is always considered as the vital factor in the learning process. Language is one of the arts of living that can be learned only by practicing. For example, no one learns to speak the language by reading a book, but learns by practicing and interacting with others. Inquiry-based learning also focuses on language and environment. As in Rogoff's (1994, p. 209) learning communities, where "learning occurs as people participate in shared endeavors with others, with all playing active, but often asymmetrical roles in sociocultural activity", the learner explores through social participation. One form of inquiry learning is dialogic inquiry. The dialogic interaction between the teacher and the students gives the teacher an opportunity to facilitate the student towards the meaning-making process. Scott and Mortimer (2006) have identified four fundamental classes of communicative approaches in class. These fundamental classes are defined by characterizing the talk between the teacher and students along each of the two dimensions, "dialogic–authoritative" and "interactive–non-interactive". According to their research, an interaction pattern can lead to cognitive development in class.

3. Cooperative learning

Cooperate learning has been considered as an important asset in inquiry learning. Working in groups not only motivates the student to help each other, but also helps in individual cognitive

development. Learners get a different perspective on a single subject and interaction with the same age group has the advantage of building up their confidence. For successful group learning, students should not only interact and communicate their views and results, but also be open minded to accept others' findings. In other words, to present his perspectives in a group, a student needs to find a reason to support it. This inspires the student to explore, construct, explain and debate the results for a firm conclusion, which forms the basis of inquiry-based learning in the definition stated above. “Reviewers of the cooperative learning literature have long concluded that cooperative learning has its greatest effects on student learning when groups are recognized or rewarded based on individual learning of their members" (Slavin 1996). In addition, Krajcik et al. (1998) quoted Bruer (1994) in his description on the role of collaboration in inquiry: “Collaboration helps students construct knowledge and introduces them to disciplinary language, values, and ways of knowing. As students converse, they must articulate their ideas clearly, and consider and draw on the expertise of others”. In inquiry-based learning, the group activities in which each student has his own individual assignment and altogether form the final product should be encouraged.

4. Authentic learning

In education, authentic learning is an instructional approach that allows students to explore, discuss, and meaningfully construct concepts and relationships in contexts that involve real-world problems and projects that are relevant to the learner [1]. Learning through activity and experiencing the real world, in other words, we can define authentic learning as developing skills by experiencing the real world activity which can be helpful in future challenges. As defined by Linn et al, (2004) “inquiry is the intention of diagnosing problems and critiquing experiments”. In inquiry-based learning, students based on their personal experience, find the problem and accordingly plan the activity in the real world context. This real world context learning not only surprises and motivates the student, but things begin to make more sense compared to just what is said by the teacher or the books. By using computer programming, students can also do the delicate, expensive and challenging experiments of science in the classroom and can have an authentic learning. In inquiry instruction, the field trips are common practice and they help the students to explore science in the real world context.

5. Authority of the problem and process

In inquiry-based learning, the student not only has freedom to choose the process but also the

product. This not only motivates the student but gives responsibility of the problem. In this modern era of science and technology, we need critical thinkers and not only followers. Linn et al. (2004) defines inquiry as "researching, searching for, constructing models" based on personal thinking similar to the metaphor "All knowledge is constructed; all learning is a process of construction". Knowledge is not static but dynamic, and students learn through exploration. Exploration with personal interest is not only motivating but also helps in developing confidence. When students are invited to take part in the learning process from start to finish, they experience a sense of urgency and responsibility for their learning, an approach that lends itself to greater student engagement and intrinsic motivation (Ryan & Deci, 2000). Even in the National Research Council's (1996) inquiry definition: "making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results", students are considered more as self-directed, responsible and having the authority to process the knowledge. This authority of the problem gives the student confidence to ask good questions, find results, consult with the experts and even communicate the inferences. This not only helps them build their self-confidence but increases their motivation to work as a scientist. Friesen and Scott (2013) cited Shymansky et al. (1990) findings that inquiry-based learning helped students gain greater competencies in the scientific process.

6. Teacher's role as facilitator

The role of a teacher in the inquiry process is to support the students in exploration. Through this teacher's support the students can achieve more than the personal individual level, which is called zone of proximal development (ZPD) by Vygotsky (See chapter 3 for the details). The teacher is a strong link between the learner and the process of learning. The teacher not only plans the inquiry, but also plans how this inquiry can end in a meaningful experience that can be used in the future. Only implementing is not always the best way for learning. The important thing to consider is what makes the students gain conceptual development. The teacher plays a very important role in the learning process, but it is not clear why in the definition of inquiry the role of the teacher is not mentioned clearly. This can be one of the future topics to be explored in inquiry research. This undefined role of the teacher has created lots of confusion for new teachers. Likewise, any other learning theory in inquiry-based

learning, teachers also plan their lessons but the target is how the students will construct their knowledge instead of how they can transform their knowledge to the students. As for constructing any new knowledge we consider prior knowledge and interest as very important factors in inquiry-based learning.

Summing up

Based on the literature review, the six main characteristics/key concepts of inquiry-based learning are: cognitive development, social and cultural context, cooperative learning, authentic learning, authority of the problem and process and teacher's role as a facilitator as identified and elaborated in the previous section. These characteristics not only represent inquiry-based learning but even help to explore the underlining strength and qualities of inquiry-based learning. Therefore, these characteristics are used as key concepts of inquiry-based learning for discussing the different learning theories in the context of inquiry-based learning in Chapter 3.

CHAPTER 3. THEORETICAL ANALYSIS: HOW DO THEORIES OF LEARNING SUPPORT INQUIRY-BASED LEARNING?

Introduction

It is said that "There's nothing as practical as good theory and there's been nothing as theoretically interesting as good practice[2"]. Theory and practice have always been complementary. Thus, this first non-empirical part of the manuscript probes the relation of perspectives learning to one specific practice of instruction in inquiry-based approaches. The focus is to investigate the first research question of the study: “In what ways do various views of learning support inquiry approaches in science teaching”? A short review of inquiry and learning theories is given, followed by examining the key concepts of inquiry-based learning identified in Chapter 2 from the perspectives of learning. Specifically, we discuss three perspectives of learning of Vygotsky's, Piaget's and Dewey's and its link to these key concepts of inquiry-based learning.

Inquiry and learning theories

Inquiry is drawing meaning and finding solution based on personal and social experiences. More specifically, it deals with engaging with the content/material in question, investigating and collaborating to make inferences. Inquiry-based learning is the philosophy and learning instructions. The philosophy of inquiry-based learning is based on beliefs of theories such as the work of Vygotsky, Dewey, Piaget and others, and can be considered as constructivist philosophy. Minner et al. (2009) describes inquiry instructions under the heading "Defining Inquiry Science Instruction": “It is difficult to exactly trace the first appearance of inquiry instruction, but it was born out of the longstanding dialogue about the nature of learning and teaching, in particular from the work of Jean Piaget, Lev Vygotsky, and David Ausubel. The work of these theorists were blended into the philosophy of learning known as constructivism (Cakir, 2008), which were then used to shape instructional materials. These kinds of constructivism-based materials are commonly classified under the moniker of inquiry-based learning and include hands-on activities as a way to motivate and engage students while concretizing science concepts.” Both Minner et al. (2009) and Cazir (2008) state that constructivism is a philosophy of learning. Cazir (2008) stressed that “Constructivism is more a philosophy, not a strategy”. Henceforth, it can be said that inquiry-based learning is a

practical application of constructivist theory of learning, or in other words, in inquiry-based learning the instruction material is motivated by the constructivist theory learning.

Constructivism is a theory based on observation and scientific study about how people learn. The meaning of constructivism varies according to one's perspective and position. For example, personal constructivism was described by Piaget (1967), social constructivism was outlined by Vygotsky (1978), radical constructivism was advocated by Von Glasersfeld (1995) and experience and learning was specified by Dewey (1934). Constructivist theory suggests that learning is an active process in which the learner uses their prior knowledge and ideas to develop a new concept of learning by interacting with the environment. It is more like a personal or a social experience. The inquiry approach is identified as one of several forms of constructivism.

The next section in this chapter concentrates on a critical review of the three most influential constructivist learning theories of Jean Piaget, John Dewey, and Lev Vygotsky and discusses the foundation upon which the inquiry-based learning has been rooted. It seeks an answer to the question "In what ways do various views of learning support inquiry approaches in science teaching". Furthermore, in this section we also examine the key concepts of inquiry highlighted in chapter 2 from these three perspectives of learning. In this discussion, it will be clear how the instructional methods are influenced by the views of learning.

Piaget and key concepts

Piaget (1896-1980) was a Swiss philosopher and is well known for his theory of cognitive development. According to him, people construct their own understanding and knowledge of the world, through material experiences and reflecting on those experiences. When someone encounters something new, he/she has to reconcile it with his previous ideas and experience, maybe changing what he/she believes, or maybe discarding the new information as irrelevant. In any case, the learner is an active creator of his own knowledge. He believed that "intelligence organizes the world by organizing itself"[3]. The cognitive development proceeds through assimilation, accommodation and equilibration. In the process "external events are assimilated into thoughts and, on the other, new and unusual mental structures are accommodated into the mental environment"[4]. Finally, the learner develops equilibration between himself and the environment. The process of assimilation, accommodation and the

equilibration repeat when the equilibrium of the learner breaks. He also described the four different stages in child development. Each stage has its own separate role in child development: (1) Sensorimotor - birth to 2 years: at this age the child is extremely egocentric and they experience through the six senses, (2) Preoperational - 2 years to 7 years; At this stage the child starts his magical thinking, (3) Concrete operational - 7 years to 11 years; the child begins his logical thinking, and (4) Formal operational (abstract thinking) - 11 years and up. Besides, he advocated that through cooperate learning "formal instruction by expert adults is less effective as a cognitive development stimulus than is a peer-mediated instruction". Specifically, children's abilities to organize patterns of behavior and thought as they formulate and interact with their environment, parents, teachers, and peer groups develop more quickly when children interact with one another than when they interact with adults (Biehler & Snowman, 1997).

Piaget in his book "To Understand Is to Invent"- expressed active learning as: "to understand is to discover, or reconstruct by rediscovery, and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simply repetition"[5]. Piaget believed in authentic learning, his focus was always on cognitive development. According to him, the learner is motivated, and gets more interested when he has the authority of the problem. He always suggested considering the learner's age as one of the important factors in the learning process which he explains in the development stage. Overall, taking into account the six key concepts of inquiry from the Piaget's perspectives of learning, it can be said that the inquiry approach is highly influenced by his philosophy. The five key concepts cognitive development, cooperate learning, authentic learning, authority on the problem and process, teacher role as facilitator all fall under Piaget's perspective. He gave importance to social and cultural aspects of learning, but his research stressed more on individual cognitive processes.

Vygotsky and key concepts

Vygotsky (1896-1934) was a Russian philosopher and psychologist known as the father of social constructivism. Social constructivism theory applies mainly to mental development, such as thought, language and the reasoning process; these abilities were understood to develop through social interaction with others. According to Vygotsky, "every function in the child's cultural development appears twice: first, on the social level, and later on the

individual level; first, between people (inter-psychological), and then inside the child (intra-psychological)"[6]. His theory explains the principles of zone of proximal development (ZPD) and More Knowledgeable Other (MKO). According to him, a student can solve a problem either independently (actual development) without the help of anyone or with the assistance of others. For example, with appropriate assistance a seven year old child can solve a problem of a higher age child, say eight, nine or higher and this difference is what we call the zone of proximal development (ZPD). Figure 1 illustrates how a child can achieve beyond his present reach with the help of scaffolding; this difference called ZPD is presented by the orange oval. It is the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or collaboration with more capable peers. Vygotsky focused on the connections between people and the sociocultural context in which they act and interact in shared experiences (Crawford, 1996).

In inquiry-based learning, cooperative learning is very common practice which reminds us of the Vygotsky philosophy - cognitive development is a product of social and cultural interaction. In inquiry-based learning, both zones of proximal development and scaffolding can be found. Thus, we can conclude that the five key concepts of inquiry- social and cultural context, cognitive development, cooperative learning, authentic learning, authority of the problem and process comes under the Vygotsky theory. His view gave primacy to social and cultural processes. His theories also stressed on thoughts and language which are one of the vital aspects of social constructivism. In his philosophy, the role of the teacher is more of a mentor than a facilitator.

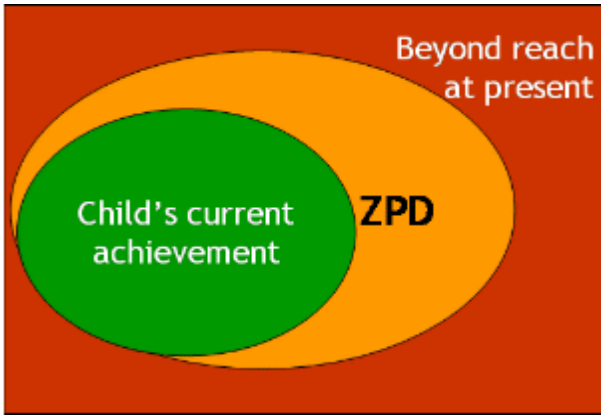

Figure 1. Illustration of the zone of proximal development (ZPD) [7]

Dewey and key concepts

John Dewey (1859-1952) was an American philosopher and his philosophy of education instrumentalism was also called pragmatism. He stressed on active learning, a real experience rather than traditional rote learning. According to him, education begins with the curiosity of the learner, “learning like a scientist”. Jeffrey Kaplan, one of his followers explains Dewey’s philosophy as: Dewey believed that teaching and learning should occur in a classroom where true participatory democracy is practiced (2002)[8]. The central goal of education, according to Dewey is to help students lead lives rich in worthwhile experiences (Wong and Pugh, 2001). He wrote, "If you have doubts about how learning happens, engage in sustained inquiry: study, ponder, consider alternative possibilities and arrive at your belief grounded in evidence"[9]. He gave connection between knowledge and action which amounts to "an experience". “Experience occurs continuously, because the interaction of live creature and environing conditions is involved in the very process of living. There are distractions and disparity in what we observe and what we think, what we desire and what we get" (Dewey, 1934, p. 35)[10]. Many progressive educators misunderstood his teaching and in response he wrote:

“There is a present tendency in so-called advanced schools of educational thought to say, in effect, let us surround pupils with materials, tools, appliances, etc. and let the pupils respond according to their own desires. Above all, let us not suggest any end or plan to the students let us not suggest to them what they shall do, for that is an unwarranted trespass upon their sacred intellectual individuality, since the essence of such individuality is to set up ends and means. Now, such a method is really stupid, for it attempts the impossible, which is always stupid, and it misconceives the condition of the independent thinking" (Dewey 1990). His epistemological approach gave importance to the social-cultural aspects in cognitive development. In student learning, an educator plays a major role, "A primary responsibility of educators is that they not only be aware of the general principle of the shaping of actual experience by environing conditions, but that they also recognize in the concrete what surroundings are conducive to having experiences that lead to growth"[11]. He argues that providing the student with enjoyable learning experiences motivates them to continue learning; this motivation matters just as much as the knowledge that is learned[11]. In his philosophy, he advocated student learning like a scientist and gave the importance to the way of learning in cognitive development with prior knowledge.

He believed that experience cannot be choreographed or presented to the student; it is an active process and emerges from active involvement with the help of the environment. Dewey's philosophy focuses on cognitive development in context to the environment. He is called the father of inquiry-based learning, as per his philosophy “learning like a scientist”, to explore in the context of the real world and have a ‘real experience' which can be further used in the real life. Inquiry-based learning, cognitive development is achieved in context of the environment and in this approach the learner is the inquirer and has the ownership of the problem which not only gives motivation, but also responsibility.

According to Dewey “Schooling is not just about the individual. It is the coming together of the child’s interests with those of the society” Crawford (1996). His philosophy stresses on the real experience which is one of the fundamentals of inquiry-based learning called prior knowledge. He also states that pedagogy should not only be interesting but also motivating. When a learner is given the authority of the problem and process, he makes the commitment based on his interest which motivates him. His teaching and philosophy are grounded in inquiry-based learning. Social and cultural aspects were always considered important in his theory of learning. He considered the role of a teacher as coach and as a facilitator.

Dewey’s philosophy highly influences inquiry-based learning. He believes in authentic learning, discovery learning and was a supporter of active learning. Like Vygotsky, he also stresses on social and cultural aspects in the learning process and gave importance to the language. He defined the experience as the ‘real experience’ that is vital and can be used in the future learning/experience. Like Piaget’s concept of disequilibrium, he explains “the state of disturbed equilibrium represents need” and motivates the learner to further learning. His teaching always considered the motivation and interest in learning as very important. Examining the key concepts from Dewey’s philosophy, we can say that all six concepts can be supported. According to his philosophy, a teacher's role is more as a facilitator than the mentor.

Similarity and dissimilarity in theories of Vygotsky, Dewey and Piaget

Dewey's philosophy has similarities with Vygotsky whose work he never read (as his work was translated into English very late). Both of them emphasized the role of culture and language in cognitive development. Dewey and Piaget emphasized the individual conceptual

development. Although Piaget's work gave the importance to social aspects in learning, his research never focuses on it. He explains that the student performs according to his level (age) but in contradiction, Vygotsky explains that students can perform higher than the actual level by scaffolding and by achieving the ZPD. Most fundamentally, however, all three theorists focus on the same real experience with respect to the real world for social progress and gave more importance to progressive teaching and learning than the traditional rote method.

Comparing Dewey's philosophy to Vygotsky and Piaget, "Dewey's argumentation enables to take both the subjective (individual) and intersubjective (sociocultural) dimensions of the construction of knowledge into account within the same constructivist framework (Vanderstraeten and Biesta 1998)". So, Dewey's theory brings together the other two theories or makes a link between them. "Dewey, a philosopher attuned to the contributions of psychology, can help educators in their ongoing struggles to theorize the practical implications of Vygotsky and Piaget for democratic classrooms" (Mayer 2008). Dewey's theories not only integrate the theories of Vygotsky and Piaget but also gave an ease in the practical application of both theories in classrooms. Mayer's article "Dewey's Dynamic Integration of Vygotsky and Piaget" also gives a clear link between the three theories. Besides, Dewey's epistemological approach can be seen as a bridge or integration of the two philosophies of Vygotsky and Piaget. Figure 2 illustrates this overlap and is the theoretical model for the empirical study in this thesis. The figure represents that individually all three theorists Dewey, Vygotsky and Piaget are the major contributors of constructivism. But, Dewey's theories bridge the other two theories and even ease its practical application.

At the end, the inquiry-based learning finds its antecedents in all three theories and is a blend of all of them. In other words we can say that the inquiry-based learning has constructivism as its root. However, Dewey's interlink of the two theories makes practical instructions more feasible.

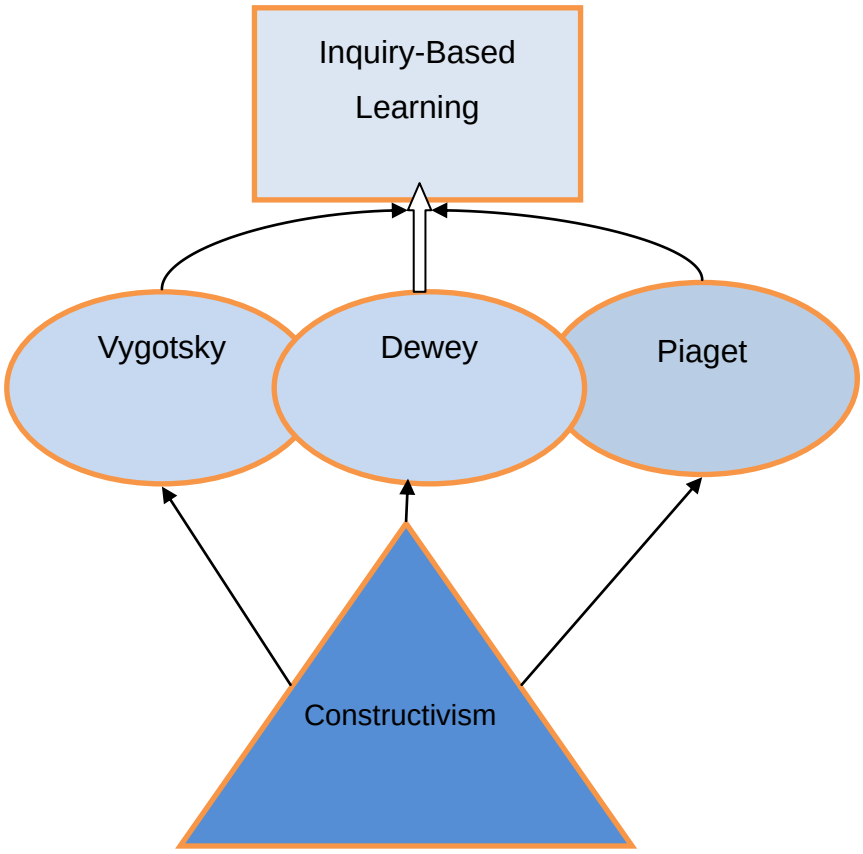

Figure 2. Theoretical model based on the literature review

This theoretical model (figure 2) is quite similar to Belinda Williams' (2003) comprehensive definition of school reform to educate all children, which she calls theoretical framework of normal human development, and is presented in Figure 3. The Foundation for a Theory of Learning and Teaching, where she stated the connection between the Dewey knowledge of experience and new knowledge to the Piaget's Codification of experience or the process and to Vygotsky's cultural and social context. However she did not discuss about the overlap of the theories as illustrated in the above figure 2.

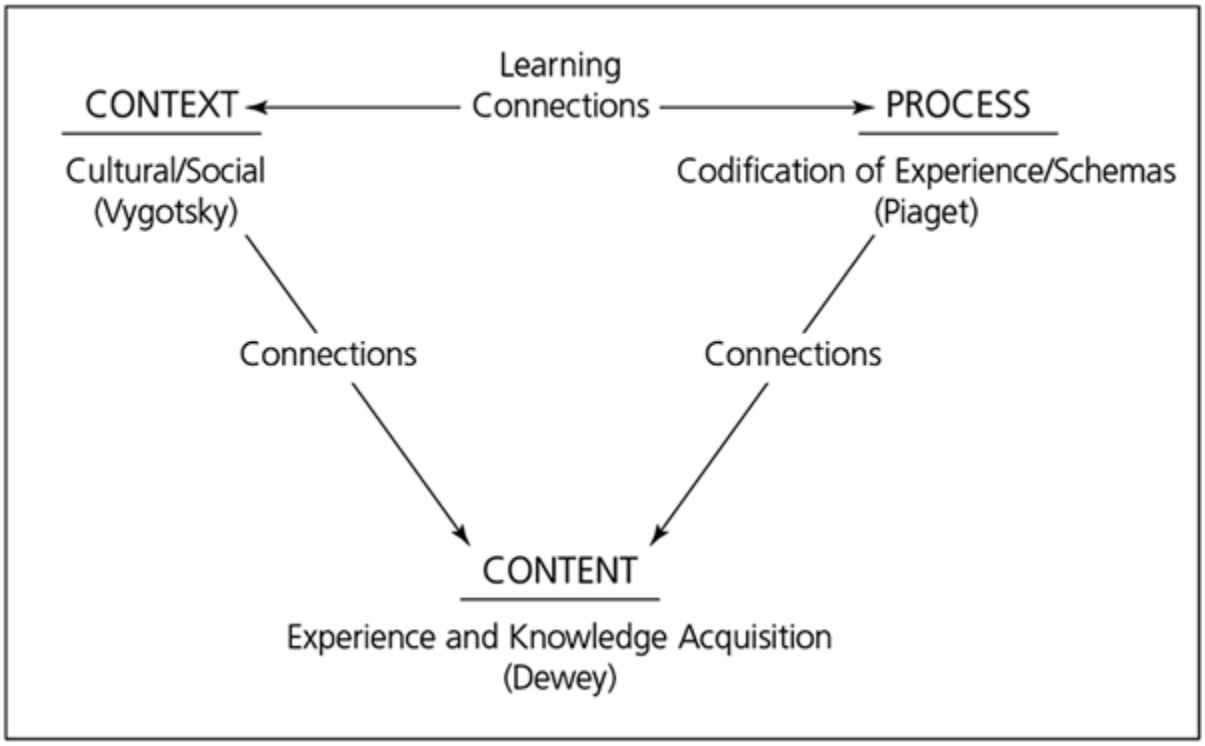

Figure 3. Toward Theoretical Integration: The Foundation for a Theory of Learning and Teaching Connections by Williams (2003).

Conclusion

Inquiry-based learning owns its philosophical and theoretical roots to philosophers and theorists such as Jean Piaget, John Dewey, and Lev Vygotsky (Doolittle and Camp, 1999). But considering the role of a teacher in Vygotsky's philosophy, which is more like a mentor, but in Dewey's philosophy, its more as facilitator, which is more commonly mentioned in inquiry-based learning. Inquiry-based learning instruction's goal is cognitive development in a social context. Cooperative learning is a common practice which focuses on Piaget's cognitive development in Vygotsky's social context. Dewey's philosophy integrates both these philosophies. Dewey's integrated theory of constructivism is explicit in inquiry-based learning and accounts very well for these claims. Recounting them, first, knowledge is actively built up from within by individuals and society where language based social interaction is central to building knowledge (Vygotsky). Second, construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences (Piaget). Third, putting all together or we can say finally construction of new knowledge with the coherency of prior individual knowledge, personal interest and the experience in the real world and the society (Dewey).

Inquiry is an instructional model which is always influenced by the environment and it is not a very easy task to express all its aspects in theory. But it can be said that inquiry-based learning exemplifies the constructivist theory and in inquiry-based learning views of learning overlap each other as shown in Figure 2.

At present, some of the definitions stress either on cognitive learning or on the cooperative learning, but to the author’s knowledge, none of the definitions clearly discuss about a teacher's role in inquiry-based learning. Sometimes teachers are unclear about their role in inquiry-based learning. Thus the second part (the empirical case study) of the study attempts to investigate the teachers' perceptions on inquiry-based learning.

CHAPTER 4. THE EMPIRICAL CASE STUDY

The Empirical case study is the central aim of the present study with focus to investigate teacher views on the inquiry-based learning with help of the research question mentioned below in section 4.1.

This empirical part of this study not only attempted to investigate teachers' personal views on the content and aims of inquiry-based science teaching but has even tried to find the constraints that an in-service teacher faces in using the inquiry approach. Furthermore, even endeavor to find what according to the in service teacher should be done to support the teacher for using the inquiry approach. Besides also finds the relevancy of theory and views of teachers on inquiry-based learning and practice.

This chapter clarifies the techniques and procedures that are appealed in the present study to answer the research question. It justifies usage of those techniques and highlights their advantages during the process of the study. The details of the case study conducted and the IB program followed by the school is presented in Section 4.2. Section 4.3 provides details on research design and methods and discusses the methodology chosen and its justification. The next Section 4.4 provides information on how and when the interviews were conducted. Section 4.5 presents data analysis and Section 4.6 gives the details about the teacher's backgrounds and qualifications. The last section 4.7 throws light on the ethical issues with respect to the present case study.

4.1. Research questions

2) What are the teachers' personal views on the content and aims of inquiry-based science teaching?

3) How do these views relate to what they consider to be inquiry-oriented approaches from their own teaching practice?

4) What are the constraints that teachers face in designing or executing the inquiry lesson?

4.2. The case

The study was undertaken as a case study of five teachers working at Trondheim International School (THIS) in Norway. A primary reason for choosing THIS is that it is an International Baccalaureate (IB) School, where inquiry-based teaching approaches form a part of the school policy. All teachers were therefore familiar with inquiry-based approach which was pivotal for this study. Otherwise the researcher would have to explain to the teachers what inquiry is and only then the teachers could be interviewed. In that case, the data could have a researcher bias, which could affect the internal validity. Furthermore, the researcher was working part time in THIS school which created a very friendly atmosphere and flexibility during the interviews. All the teachers interviewed were familiar with the researcher, so they were very open to discuss and give their comments. The data were collected during the academic year 2011-2012 from the Primary Years Program (PYP) and Middle Years Program (MYP) teachers. The PYP (1-6th grade) teachers teach science as an integrated subject together with other subjects. The teachers were of different nationalities and had their training in science as well as teacher training from various countries. All five teachers had either a bachelor degree or a master's in education and two of them had a background in science. Their teaching experience in science ranged from 11 to 30 years. Due to ethical considerations all names in the article are fictitious. Details of the teachers' educational background, experience are provided in Sections 4.6.

In the International Baccalaureate (IB) curriculum, each unit planner has the unit name followed by central idea which gives a clearer picture of the unit and has the lines of inquiry to clarify the central ideas. The central idea and lines of inquiry help the teacher to plan their lessons according to the need of the curriculum. In particular, the teachers use this line of inquiry to make stronger, conceptual teacher questions, for example, how or why. These are the questions to be displayed in the classroom and help guide students inquiry or in other words to initiate their inquiry. After each year, teachers evaluate the inquiry line and the central idea subsequently by revision or rewriting sentences presenting the central idea if needed. These IB teachers considered the central idea very important and used it as the base for planning the unit, executing and also for assessment. All the teachers used the terms inquiry-based learning, central idea and line of inquiry very often during their interviews.

4.3. Research design and methods

This section deals with the research method chosen for this study and provides justification for the choice.

Methodology: choice and justification

The aim of the present study was to find the relevancy of theory and beliefs of teachers in the context of inquiry-based learning. The focus of the present study is qualitative data "The teacher's perception" so flexible design strategy was considered to be the choice of interest. As flexible design strategy is said to be exploratory, it's the collection, analysis and interpretation of data by observing human behavior. There are three traditional flexible designs which are more relevant to the real world study - case study, ethnographic, grounded study type. Case studies are used to collect descriptive data through the intensive examination of an event in a particular group, organization or situation. According to Yin (1994) the case study is a strategy for doing research which involves an empirical investigation of particular contemporary phenomena within its real life context using multiple sources of evidence. The study attempts to investigate the existing inquiry practice from the teacher's perceptions. Thus, the case study approach is highly appropriate method for it.

The justification for use of this methodology to investigate contemporary phenomena in different areas, including psychology, sociology, political science, history, anthropology, economic management, has been recognized by many researchers [12]. The main advantage of using case studies is that they show how things occur in practice and therefore this can be useful for the researchers, teachers and curriculum developers.

4.4. Interviews

The research data were collected from the Primary Years Program (PYP, age 6-11 years) and Middle Years Program (MYP, age 12-15 years) at THIS School. The PYP teachers teach science as an integrated subject together with other subjects. The qualitative data was gathered by means of audio recorded semi-structured interviews. Individual interviews were conducted by the researcher.

Before interview: Informing teachers about the project in the staff meeting:

After taking permission from the school principal for carrying out my research project at THIS school, the teachers were invited to take part in my research study. During a staff meeting, I presented my research project and data collection process to the teachers. In particular, I emphasized that the purpose of this research was not to evaluate the teacher's way of teaching but to find how different instructional approaches are used in different classrooms and graded. Besides, similar studies have been done in many parts of the world and the methodology for data collection was motivated by the Gyllenpalm et al. (2010) study "traditional teaching" in Sweden.

Particularly, for my research, I would require the data from a teacher who teaches science as a subject. In general, I would collect data via structured interviews with the teacher, which comprises about an hour from their schedule. Additionally, I noted that during the interview, I would ask the teacher to describe their typical or "best case scenario" from their own teaching practice that they believe constituted inquiry-oriented teaching. So I requested all science teachers to think and prepare an example and bring along the manipulative that they may need to describe their inquiry example. I informed them that I would contact each teacher personally and make an appointment for the interview.

The data would be audio recorded and important notes will be taken during the interview. The recording is to accurately record the information they (teacher) provide, and will be used for transcription purposes only. The audio tape will be kept confidential and will be destroyed soon after the completion of my project. All the teachers were very open for the research project and two teachers commented that it will be exciting.

Preparations for the interview

Various preparations were done beforehand like checking the audio recorder and making the question sheet with the space to allow taking notes. Additionally, a day before the interview the teachers were sent an email to remind them about the interview and other necessary details. This was to ensure that the teacher remembers to bring their example and bring along the manipulative if required.

Prior to the interview, to direct the conversation toward the aimed topics and issues an

interview guide was built. The interview guide (Appendix 1) was grounded on the literature review and also acknowledges the research question and the interview ethics. The interview guide was based on theoretical discourse on the subject. There were twelve questions in total. All of the questions were open-ended in order to allow the teachers to contribute with as much detailed information as possible, and provide for the researcher to ask probing questions as a means of follow-up. The sequences of the questions were usually dependent on the flow of conversation. Predefined questions in the interview guide included questions on the teacher's view on inquiry-based teaching approaches in general, and on a concrete lesson from their practice they considered to be an example of inquiry-based teaching. For this, the teachers were asked to describe their goals and how students responded, what they learnt and what challenges they faced. The teacher's experiences with professional development and constraints in performing inquiry-based teaching and how they could be overcome were also addressed in the interview.

Before the final interviews, a pilot study was conducted at the school from a teacher. This was performed to develop and test an adequacy of research instruments and assess the feasibility of the study. The interview started with basic questions on experience and educational background and then the teacher was asked to describe examples of their own teaching practice that they believed constituted inquiry-oriented teaching. This created a natural classroom environment and the teacher took interest to explain and give their views. The result of the pilot interview showed that the instrument was appropriate for the goal of the study. So no changes were made in the interview guide.

The interviews were fully transcribed for analysis but in the result chapter 5, the wording has been slightly modified to put the different sentences in the paragraph in order to make the flow smoother or to add relevant information to make sense but have tried to retain the original meaning of the text.

4.5. Data Analysis

Data analysis commenced with transcription of the recorded interviews. Interviews were fully transcribed for analysis. To organize and manage the data the qualitative software ATLAS.ti (1999) Version 4.2, was used. Three broad tasks for qualitative data analysis were

described by Miles and Huberman (1994) as data reduction, data display, and conclusion drawing or verification. Obviously all the three tasks stated by Miles and Huberman (1994) are covered in the inductive analysis, consequently, inductive approach was chosen for the analysis the data. "The purposes for using an inductive approach are: (1) to condense extensive and varied raw text data into a brief, summary format; (2) to establish clear links between the research objectives and the summary findings derived from the raw data and (3) to develop a model or theory about the underlying structure of experiences or processes which are evident in the raw data" (Thomas, 2006).

Thomas (2006) mentioned that the primary purpose of the inductive approach is to allow research findings to emerge from the frequent, dominant or significant themes inherent in raw data, without the restraints imposed by structured methodologies. The interview transcripts were read several times in order to analyze the themes of inquiry-based learning that the teachers emphasized while defining inquiry-based learning and the themes that emerged from the teachers' descriptions of their own teaching practice examples. Codes were developed by studying the transcripts repeatedly and considering possible meanings and how these fitted with developing themes across the individual teachers. The different codes were used to form or present the themes for example codes- science and world, inventor coming in, and do experiment make it real all this codes come under a theme real world connection. A rigorous and systematic reading and coding of the transcripts allowed major themes to emerge. In particular, all the transcripts were read by the researcher and the identified themes were discussed with the supervisor. After discussion, a coding frame was developed and the transcripts coded by the researcher. If new codes emerged, the coding frame was changed and the transcripts were re-read according to the new structure. This process was used to develop themes, which were then conceptualized into broad themes after further discussion. Summaries of each code were constructed and then compared and refined across the informants. The identified themes are discussed in detail in the Chapter 5.

4.6. Presentation of individual teachers

The data was collected from an International school. I chose THIS because all the teachers at THIS school were familiar with the inquiry-based learning approach. Additionally the teachers were from the different parts of the world with the different backgrounds which

provided wider range of perception to my data. It's just a coincidence that all the science teachers at THIS are female.

For the present study the researcher requested all the science teachers to participate in the study. Fortunately, all the class teachers of PYP (1-6) who teach science as an integrated subject accepted to participate in my study and in addition, the MYP (7-10) science teacher also agreed to participate. I booked appointments for the interview with all the teachers based on their availability. However, grade 1 class teacher was on an emergency visit to her home town and thus I was unable to set an interview with her. Besides, in the next proceeding school year, the teachers were allotted different grades than the previous year, for example, grade one and grade two teachers were interchanged, grade six teacher moved to Tokyo and grade 5 teacher was allotted grade 6 etc. Additionally, grade 3 teacher was on sick leave for a long time and subsequently busy, so the interview was postponed several times. As a consequence her interview was not transcribed and included in the study due to time constraints. The remaining five teachers' interviews were transcribed and included. Details of the all the five teachers are given below.

Camilla.

Camilla taught in grade 5 (PYP). She has 14 years of experience in teaching elementary science. She holds a Masters in elementary education from the USA and also has a Masters in school development from Norway. Additionally, she has a degree in reading instruction.

Jane.

Jane taught in grade 6 (PYP). She has 11-12 years teaching experience from grade 3 down to preschool. She holds a Bachelor in education in early childhood. Before coming to Trondheim, she was working in Australia with a similar frame of IB. Subsequently, after joining THIS school, she has taken some online IB professional development courses and also did undergone IB special training.

Rachel.

Rachel taught in grade 4 (PYP). She has 30 years of teaching experience in PYP. She holds a Bachelor in education and have been working in the IB school since two years. She has taken the course PYP making it happen. Additionally, she has undertaken two IB professional

developments training to be an inquiry-based learning based teacher, the first was an on-line course and the other one in Dubai. Besides, she had been teaching with a similar inquiry concept in Australia but use different terminology.

Sandy.

Sandy taught in grade 1 (PYP). She has 14 years of teaching experience in lower primary and preschool. She was trained from multi educational in the primary in California and also has teaching credentials from California. She has under graduation in German literature and teaching as a minor and psychology as the minor, it's a clad which is more multi-cultural credential focused on multi-cultural education.

Valentine.

Valentine was MYP science teacher and MYP coordinator. She has 11 years of teaching experience, with 2 years in MYP and 9 years in PYP. She holds Bachelor of Arts, and also Bachelor of Science from ANU University in Australia and a Bachelors of Education from a different university in Australia. Additionally, she has a graduate certificate in business.

4.7. Ethical issues

To execute the research at the school, prior permission was taken from the principal. After his approval, the teachers were informed about the research purpose in a staff meeting and invited to participate in the study. They were contacted individually to make an appointment. On few occasions, the interviews were postponed, if they were busy, sick or unavailable. All the interviews were conducted considering the teacher's conveniences of day and time to avoid any kind of mental or physical stress for the teacher. For instance, if a teacher had a busy day we postponed the interview to avoid the teacher from being tired and demotivated during the interview process. The interview location was always chosen by the teacher, for example, their own classroom or the library etc.

CHAPTER 5. RESULTS AND ANALYSIS

This chapter has been divided into three sections to answer the remaining three research questions of the study. As the first research question was non empirical and literature based, it's been already delineated in chapter 2. The next 3 research questions are answered by the empirical case study and are presented in this chapter. Section 5.1 answers the second research question "What are the teachers' personal views on the content and aims of inquiry-based science teaching?" Sections 5.1.a and 5.1.b illustrate the teachers' personal views on inquiry-based learning and a concrete example of inquiry-based teaching of their own teaching practice respectively. Besides, section 5.1 also presents the teacher's views on alternative way of teaching rather than inquiry based learning and helps to find how teachers differentiate inquiry from other ways of teaching. In section 5.2, I have tried to find the intermediary between the teacher's views on inquiry and the teacher's own example of their inquiry lesson, this section answers the 3rd research question.

Teaching is a challenging job, when it comes to different learning theories; teachers face many constraints in planning or executing the lesson considering the learning theory. Moreover section 5.3 tries to throw light on these constraints from the teacher's perceptions and answers the last research question of the present study. Furthermore, it also illustrates what according to the teachers can help in enhancing the use of inquiry approaches. The limitations of the present study are also discussed in this section.

5.1. a. Teacher views on inquiry-based learning.

In the interview, the teachers were asked about their personal views on inquiry-based learning. In the teachers' responses, the researcher was looking for their understanding of inquiry-based approaches and the issues they considered most important. The study revealed that each teacher applauded inquiry and considered it to be very important which is explicated from their comments such as "*I love it*", "*it's a natural way to learn*", "*it suits my philosophy*" and "*it is very good*".

Analysis of data on the teachers' views on inquiry resulted in five broad themes- Motivation, Making connection, Developing a questioning mind, Students' freedom, and Student ownership. All these themes were represented in how several teachers described their view on

inquiry-based teaching. The themes are presented below, exemplified by one quotation for each theme. Although, all the teachers used these themes while describing their views on inquiry-based learning and practice, the quotations were taken from the teacher who stressed more on any one of the five.

Motivation:

Motivation is one of the important factors in teaching and learning process. Teachers see inquiry-based approaches as motivating for the students and a way to get them involved in science.

Camilla: "*I think it's very good, especially for the students who have low motivation. It's a way to get them involved, take some ownership, and really go in a direction which is interesting for them*."

Motivation has many times been one of the foremost challenges for teachers. But most of the teachers have the opinion that inquiry-based approaches are not only good for normal and high motivated students, but is even better for low motivated students. The reason they gave is that an inquiry approach is very open in making choices for learning. Obviously, students are different and have different areas of interest considering this the inquiry-based learning approach lets the students find their own interest-based connection to the theme or the concepts and keep them motivated for the learning.

Making Connections:

Teachers see inquiry-based learning as a way of connecting elements of knowledge in holistic and meaningful ways.

Valentine: "*I think it's a natural way to learn, you learn when you like, and you intensely make another connection to things in your brain. Inquiry is based on people pursuing in a way that you make more connections, synaptic connections*."

The teacher believes that, in inquiry-based learning, there are many ways of doing one thing. It can be done through different interest areas and having some connection to the topic. To clarify the point, Valentine exemplifies "*if you have to learn about the dogs and if you don't like dogs than you don't have the personal connection in the information collection. But you might be interested in an anatomy of dogs, you might be interested in the behavior of dogs, you still might not like dogs but you got these other interests. So inquiry will let you pursue the other interest, it's just about the central thing dogs*".

According to the MYP teacher Valentine, it's obvious that a student who likes the topic would be interested in researching and finding more about the topic, but this making connection concept facilitates learning for the student with low motivation by finding some connection to the topic in their own area of interest.

Teachers think making a connection to the theme for learning not only motivate students, but also help them in future to re-apply the knowledge in different contexts. This is one of the key phases in the learning process.

Developing a questioning mind:

Teachers see inquiry-based learning as a way of developing students' curiosity and will to learn. This resembles what Earl and Katz (2002) call "Inquiry habit of Mind" presented in chapter 2. Jane stresses on a "questioning mind" in her example as "*It is extremely important to keep the questioning mind of a toddler still when you are a teenager*".

According to Jane, the questioning mind is not only important for the student learning, but also to make them a better citizen of the country. She explains it as follows "*I think without an inquiry you are just force feeding somebody something, it would be like eating baked beans every day. I think inquiry makes you question the world around you, I think that the class of 20-25 children, that will be the future adults, and then they need to question their environment otherwise there won't be any environment around them they need to be able to question! For example, should we use so much oil to make any plastic and should we recycle plastic etc.* According to her "*If we don't get those inquiries thinking happening early, people can be left behind*".

Students' freedom:

Teachers emphasize students' freedom in teaching activities, and see inquiry-based teaching approaches as a way of transferring control from the teacher to the students. According to the teacher, this trust of the teacher towards the student not only gives them the motivation, but also gives them the confidence to take the decisions. The teacher of grade 4 Rachel stresses that "*In an inquiry class, students are given freedom to make decisions and the teachers trust the students.*"

If the teachers trust the student and give them the freedom to explore, there is a higher chance

to have a more open inquiry. If the teachers lack this trust, it's a more structured inquiry. In other words we can say it will be more teachers led then the student led as the teacher decides both the inquiry question and the method, consequently, students have less freedom. So without this trust and freedom, the inquiry based approach loses its essence of inquiry and there will be no open inquiry in the classroom.

Student ownership:

Teachers see the openness of inquiry as a way of developing students' responsibility and to give them ownership of their results. Whenever a learner succeeds at a task all by himself, of course under the teacher's supervision, he gets the feeling of satisfaction; it also increases their self-efficacy.

According to Sandy: "*Children grow and take responsibility for their learning. I see them excited about something that they come up with, connecting it to the world and sharing their new knowledge and their discoveries. It is really valuable*".

What characterizes teacher's views on inquiry-based teaching?

In summary, we can conclude that teachers value inquiry-based teaching as it is good for low motivated students, it gets students involved, lets them explore according to their interest and make connections. It also develops the students' questioning mind, freedom to make decisions and their ownership of learning. This indicates that the teachers value inquiry-based teaching as student-centered teaching where student autonomy is considered as the most important. So, if we put all the characteristics of inquiry in a diagram (See figure 4) we can see that all the five characteristics of inquiry-based learning leaning towards the central characteristics student autonomy. Figure 4 not only demonstrates inquiry-based learning as very student centered but also highlights the basic essence of inquiry "Student Autonomy".

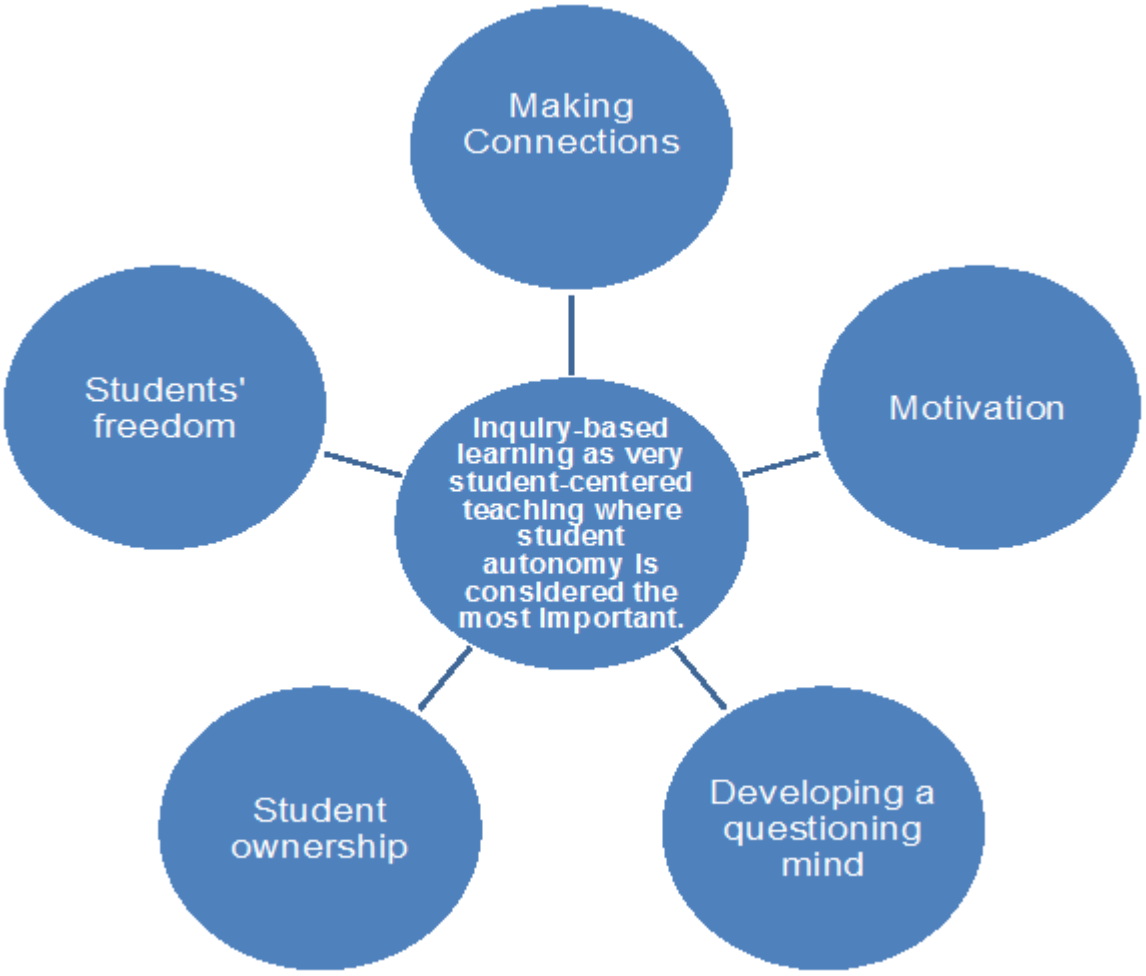

Figure 4: Themes highlighted from the teacher views on inquiry-based learning.

This could signal that teachers pay less attention to students' subject learning in the inquiry-based activities. However, when we analyzed the example described by teachers of their own teaching practice, it is found that they do consider many other aims when undertaking an inquiry lesson. The section 5.1.b explains this in detail.

Teachers views on other ways of teaching

In the interview, the teachers were also asked to describe their views on other way of teaching rather than inquiry. In the teachers' responses, we were looking for how the teachers differentiate inquiry-based approaches from the other ways of teaching. They used different expressions to describe what inquiry-based learning is and what it isn't. It was very interesting to find how the teachers perceive other ways of teaching. Below we provide the gist of the comments from the teachers.

Camila describes it as: "*I think it is topic based, very teacher led, teacher directed*."

Jane calls it as: "*I would call other way teaching as only drills, no skills, and no thrills".*

She explained the difference between the skills drills and thrills as follows. *"The skills where I do the explicit teaching, I explicitly give them the information, I paraphrased it. I double check with the kids that they know that's the skills , drills are just straight of this exactly how you use it, this is where it is, this is how you use it, this is how you work, this is when you got it wrong, this is how you do it. The thrills are how to apply, how to transfer it how to explore and thrills are the inquire part. So I call skills, drills and thrills, as Jane's vision of inquiry teaching*.

Rachel explains: "*you write notes from the board into your book, and you learn the facts, you memorize them and you forget them each day*."

According to Sandy: *"I guess more directive teaching where, the teacher is the owner of the knowledge"*

The teachers see other ways of teaching as more teacher-centered directive, topic based, drill, and memorizing. According to them, it's not student centered as student interest is not considered very important. But most of them didn't want to call it as the traditional way of teaching. As expressed by Rachel "*People say traditional way, but when you say that we will be traditional because there was always a teacher didn't teach that way.....all teachers teach differently, I don't think that's quite the right word, we always have had science lab, so right from the start science was meant to be something that students did and was hands on*."

5.1. b. Teachers' examples of inquiry-based learning activities.

Introduction

In this section, we present five examples of teachers' descriptions of their concrete approach to inquiry in their teaching. In the examples, the teacher used the words unit of inquiry which is the topic given in the curriculum. They also used the central idea which is the focus of the unit. The central idea is discussed in detail in the section 5.3.

Camilla's example: Inventors

Camilla is a PYP teacher describes the inquiry example as following:

Unit of inquiry: Inventor

Central idea: Technology has changed the world of work and leisure.

Camilla's starting task was to let students draw a simple sketch of what they think an inventor looks like, and then what kind of person do you have to be to be an inventor.

She explains: "*I wanted to see what they believe an inventor is and do they think they could be inventors. We also had really explored the central idea, that's very important to do in the beginning. We did Venn diagrams: What technology has changed the work, what technology has changed leisure? And which ones will go in the middle for both. We had an inventor came to talk about how he got started as a child at the age of nine, that's the student's age. This also gives another prospective of what's like to be an inventor. He was teaching them the process of inventing, or his process and teaching them there is not only one way. And from that they were asked to research a simple invention that has changed the world of work or leisure or both. And they were going to investigate and gather research and make a PowerPoint presentation.*"

Camilla shows how she develops the inquiry from students' prior knowledge, to connecting to the real world, to applying knowledge and gets to new knowledge as the process of inquiry to achieve the final product of the inquiry the curriculum.

Jane's example: Diseases

Jane is the PYP teacher her inquiry is as follows:

Unit of inquiry: Diseases

Central idea: Although people have discovered many ways of preventing and coping with diseases, the pursuit of preventing, curing and supporting people with various illnesses continues through the work of organizations.

Jane explains: "*We at the moment are doing a unit of inquiry around diseases, and the illness and suffering that occur from it. As part of science, we are looking at tests and procedure to check whether you have that disease. This links it to the real world; it links it to our unit of inquiry and gives us some science-based experiments in the science lab. Today I am going to talk about chromatography. It's something which is used a lot in the outside world from the genetics all the way down to the urinary test. I provide kids with information through a video*

which shows how the test is done so that they see what is happening. We use their background knowledge of acid and bases and how different chemicals would have different shades within the color, pulls it together and we go down to the lab where we do a simple experiment with the mark pens so that they can physically see and work out what it is. I give them the basic information first and I tell them what they are doing ok. From that we brainstorm, think, care, and share and do a Venn diagram of different things so that we can work out the range of knowledge within the class. From there, we do an inquiry into treatments. Then they go off, they find the treatment themselves, they came back and told me all sorts of different treatment. They use researching skills on the Internet, they use their parents for knowledge and they use first-hand experience. But when you have to take it down to the science lab, you have sort of, I feel you have to funnel it back down to something small. So they can physically do it. But then they make the connections back out from the funnel so it's like a little tree."

Jane's example had the similar phrases of prior knowledge, connecting to the real world, exploring and applying to get new knowledge as the other teachers. She let the student wonder about the topic and help them develop their conceptions. When it comes to hands-on activity, she helps them to link it to some simpler things which are physically possible in the lab, and that aims at achieving the content knowledge.

Valentine's example: Chemical Reactions

Valentine is the MYP teacher; she gave an example as follows:
Unit of inquiry: Chemical Reaction.
Central idea/unit question: What would the world be like without chemical reaction?
Valentine explains: "*The inquiry that I had was investigated. I had them look into chemical reactions. They had to name chemical reactions; they had to find out about - where it occurs, what the name of it is, what the starting product is and what the end product is after the reaction. They have to explore why it happens and where it happens. What is the chemical reaction for, do humans use this chemical reaction for any specific reason and then also explore what would the world be like without it. So there are lots and lots of questions just based on chemical reactions and the idea as in this example is it they see chemical reaction in science connection to a world which was the main thing. Then how they communicate this, during the process I was available with resources and with my knowledge. It wasn't necessary assessing knowledge. I was assessing how they could find things so it's a very open question*

or open idea with lots of questions attached to it. They could explore different ways and they needn't have to answer all questions. It was open enough for them to explore things in their own pace and for their interest. So it is inquiry because they had to present something in their interest range, and then what I was looking at was the links they make."

Valentine let the student explore according to their interest, she stresses that students can make different links to the topic depending on the interest and keep them motivated for the learning. She comments that in science you need to see how science connects to our world and then how you communicate it. They don't have to memorize content; they need to know how to apply the content literary or with literacy.

Rachel's example: Space Academy

Unit: Space Academy

Central idea: what people are going in space, impacts or effect life on earth?

During the interview, Rachel described many interesting inquiry examples. She also explained how she starts an inquiry unit, "*When we do a general unit, first part is children wondering, so they start thinking and asking question. So I start with asking very general question they are not specifically science questions, they might be math's question, or science based. Like, why Norway is so cold? So then we start to wonder. We start to put in, why we think that might happen and develop from there. Most of the inquiry comes from the students wondering when I ask them a question. We explore according to interest and need."*

Mentioned below is her inquiry example.

"*We did one whole unit on Space Academy. We looked at why we do experiment in the space station, what is difference with gravity and all the students were asked to design an experiment themselves what they thought they could do on the space station and then each child in the classroom tested each other's experiment to see if it was appropriate or not. It was more into actual scientific process more than the particular experiment but obviously lots of other information came out of that.*

So in detail, we pretend we are in international space station. What are the astronauts and scientist doing on the space station? What do we learn from people doing experiment and how does this help life on earth? So then, student just naturally research a whole lot of inventions

that we use today that have been developed for space or developed for the space station. So then we do find lot of information about. Why do they experiment in the air? How can we design an experiment on the air/earth, why the experiment is going to be different on the space station than the one we did on Earth. How can you design a fair experiment that someone else can do also.

They (student) designed their own experiments themselves, they recorded their results and first they did the experiment then re-edited it if needed. We had an open science day and the parents and visitors came in the class and did the experiments as well. Parents liked doing it, and then they recorded their results and children looked at whether they were same results from theirs or not, but then the next day we pretended we are on the space station, we were the astronauts and we did each other's experiment, it was just like lucky tip. The kids had it all set up. They have to go over and follow someone else's directions and also comment on each other's experiment, like, whether they were following it, whether they find it hard or difficult or what happened, what the results were and then in the next step, we looked at whether to agree with the critics or the comments that the other student has made.

They did the experiment more than once themselves because writing a procedure for a year four is quite tricky. For a start we looked at how you write a procedure and we did a lot of examples ourselves and they realize that you have to be very clear, how you set it out. So the learning is a more scientific process, scientific methods how scientists do their work and how reliable are the results from an experiment.

Rachel described different steps of inquiry, highlighting how she motivates students, connects her inquiry to the real world and gives the student freedom and responsibility and finally guide them in both inquiry content and the inquiry process.

Sandy's example: Light

Unit: Light
Central idea: How is light important in everyday life.
Camilla describes "*So when I teach the unit on light. I have teacher question and I have goals for the class. But I am able to guide them or give them ownership by presenting them with the material that I know will bring them in that direction instead of just feeding them the answers,*

I let them wonder about it first.

So, I start the unit with an open inquiry where I just have a section, where I have presented on the table different things to explore so shinny things, flash light, different pieces of paper that are transparent and translucent, different light sources, projector that projects on to the wall and there I have different colored slides and that are transparent or translucent. I just let them move from table to table and explore the objects and play with the light source. I go around and listen to their conversation and you really start hearing some wondering and some conclusions and some discussion about what is happening, it's very interesting. Then we come together and discuss. So this is kind of very first driving into the unit, where I just give them chance to explore openly and from there comes open discussion and a million questions as well, when they come up with a statement, the discovery or question, they write it down on postage and then we come and share that, we start to discuss and sort out our questions and statements, so we find out what we know already, or what they think they know, may not be correct but it's what we know at that point, and then what they want to find out. We start to sort them into different categories. I am just the facilitator, and I am helping them organize the information. This unit is fascinating to a first grader, they go home and they start to explore as well and they come in with their findings and share with the class.

All the questions are almost alien to the inquiry: what are the properties of light and how is light important in everyday life and all these things they just tide in beautifully, but if sometimes it goes more into one interest area for example into the relationship between color and light or more to shadows or refection or refraction then I have to think what another little trigger is? What can I do to make them start thinking, without telling them, we are also going to learn about this? So I always like not to say well, you are really interested in this but didn't even think about this. So I am going to tell you about that, I try to make it more like if I come with a provocation. For example I try like, I wanted to show you this what do you think about this and then sometimes that make them start thinking about the inquiry that we haven't touched so much on that I want them to know and had one of my goals of the unit".

Sandy highlighted four major steps in her inquiry example. The step 1 was to explore and have open discussion which resulted in millions of question and wondering. Step 2 was to narrow down this question and wondering by sorting and organizing them on the basis of what is already known to the student and what to find etc. Step 3 was to explore, experiment

according to the interest area of the student. Step 4 was to have backwards planning, this step was to double check if the aimed goal were covered through the student inquiry lessons or not. She even talked a lot about student's ownership and her role as the facilitator and the guide.

Summing up:

These five examples seem to be quite typical of the tradition of science education in this IB schools. As all the teachers' examples followed a similar trend and have similar paradigm. The teacher develops the inquiry from students wondering, aligned with students' prior knowledge, to connecting to the real world, to applying knowledge and get to new knowledge. Although the instructional approaches are varied, and teachers take many steps to fulfill the requirement of their inquiry, the knowledge aims are generally similar. All these process of inquiry is to achieve the underpinning goal of the inquiry-based curriculum.

5.2. What characterizes teacher's examples?

In section 5.1 teacher views on inquiry-based teaching were presented. Their views present that the teachers' aims for inquiry is very student-centered. However examples reveal other different aims.

Teachers also often refer to the aim like central idea, the goal of the unit and real world connection and prior knowledge in their own example of inquiry-based approaches. In section 5.3, we have elaborated these aims in details in the context of teacher examples.

Understanding the central idea:

To explain the importance of the central idea here is comment from the Camilla "*Exploring the central idea, that's very important to do it in the beginning and the main thing really understands the central idea, before you go on to make your own invention*". The teacher wanted the student to understand the central idea before they dive into the Unit. She also gave an example of the student whose concept was clear about the central idea and was shown from his piece of work (PowerPoint presentation).

The central idea of the unit was that technology has changed the world of work and leisure, the students were asked to research a simple invention that has changed the world of work or

leisure or both. Hence they were asked to investigate and gather information and make a PowerPoint presentation to show their findings.

Camilla gave example of Vincine's (a student), he *researched and chose the simple invention Velcro and found that George de Mestral was its inventor. He investigated about the inventor and found that the inventor came up with this idea during a walk with his dog. "When they both came home, there were burdock burrs (seeds) stuck to their clothing and this just gave him the idea of Velcro. So he studied the burdock burrs under the microscope to see how they are shaped and why they stick so well. This gave the inventor the thought that, can I create or invent a product that sticks like this, it's very convenient to have something's like that, stick without using a glue or something like that". In brief, Vincine explored how velcro works and how it has changed our life, tying shoes etc. This gave him insight into the idea that an everyday activity can lead to a really big idea, even though it seems small at the time, just the burdock burrs sticking to your cloth can give you a really good idea that has actually changed the way we tied our shoes and the way we can close things up.*

Teacher even gave a comparison of two student's presentation to show how important it is to understand the central idea before they proceed to the next inquiry "*Vincine's (a student) presentation was very short but it really fitted in (central idea), whereas the other student had 17 slides but it didn't really fit in. So it's just an idea that students can identify and lets me know if they really understand the central idea, before they go on to make their own invention. The Power Point itself is not the main goal of the lesson, the main thing is understanding the central idea*".

This teacher illustrated the importance of the central idea in both planning the lesson and assessing the student learning. Few of the other teachers also narrate the importance of the central idea in planning the unit and executing the lesson. Some of the examples are stated below.

Rachel: "*we cannot include the science component in each of the units. Within IB, you are supposed to look at the central idea of the unit of inquiry through the mathematical ends, through the science ends or literacy ends, etc. So we have to see what science is there and how could I bring it out of the unit, then tries to encourage students to bring that up and then*

use their natural curiosity and try and create science around that but you can't plan it exactly."

So it's the teacher perception which of the subject lens, she chooses from science, mathematics or arts or literary, to explore the unit in context of the central idea. Moreover it's very student dependent as the inquiry topics are more planted on the seeds of students' curiosity.

Additionally, Valentine thinks that the central idea not only helps the teacher in planning but also in executing the lesson. By focusing on the central thing, the teacher can plan different activities like individual or group activities and still help the students in their inquiry. So the teacher can plan the lesson activity based on the needs of the students. Furthermore, Camilla even thinks that the Central Idea and line of inquiry helps the new and young teachers focus more on learning than on planning the lesson.

Camilla describes, *I think a lot of time as a young teacher if you don't have direction, we get very preoccupied with the lesson itself and the lesson outcome that you forget about what is the big picture here, what is the idea or goal behind this. Whereas, with IB you have your central idea and you should always be going back to it and you have your lines of inquiry. So, you know I just go back to the central idea when I am designing my lesson and think: Are they following the lines of inquiry from this lesson? Can I get them into one of those lines of inquiry? If I can, then I know I am on track. But before, I think we were just kind of swimming around without any directions. Sometimes just like: Oh it will be fun to do this! But I don't know if they were so directed to any goal that I was conscious about all the time, and have thought about it enough*.

So based on the teacher's comment on the central idea, we can conclude that the teachers at the school considered the central idea very important in planning, executing and assessing the inquiry and even considered it as a good teaching tool. Central idea is a goal to which both students and teachers can refer back to check that their inquiry is on track or off the track from the targeted aim of the lesson.

Goal of the inquiry unit: Content or the process

The goal of the units is the focus of the inquiry. It's more like what a teacher expects the student to learn, understand, or know by the end of the inquiry. Depending on the need of the unit the teacher plans "inquiry for the content" or the "inquiry of the process". Both the inquiry goals are discusses in detail in the next paragraphs.

During the interview, after the description of their own example of inquiry lesson the teachers were asked for their goal of the lesson. In the following paragraph, it exemplifies how teachers teaching in different grades levels plan different activity to achieve the goals of content or the scientific process of learning. Of course, the teacher takes many different steps to help the student master many other skills along the way to the targeted goals.

Process as a goal

The goal as the inquiry process is where the teacher aims for the student to understand the process of scientific inquiry. For example, inquiry often starts with student hypothesis or the research question. Before moving further from the research question or the hypothesis, it has to be analyzed; what to find, how to find and where to find the information and finally how to put the information together to answer the research question or the hypothesis.

Here is one of the teachers comment with the aim of the lesson as a process of inquiry. Sandy explains about her lesson and the goal of the lesson as follows, *it's a lesson, but it's also a kind of introduction to the whole unit as well. So after mapping a lesson for first weeks and then further inquiry is perhaps more directed inquiry, or more individual inquiry. So it is to trigger interest and to help them organize their thoughts or knowledge or questions and to give ownership, so that they own it, because you know they are always more motivated if it comes from them. Since its hands on, it's also very motivating, to play and manipulate things. I want children to be able to demonstrate what kind of knowledge do I want them to have, what kind of skills, and how do I want them to express that, their deeper understanding after the unit, so if I know that than I am able to do that, I move backwards and think ok, for them to be able to do that, they need to know this and for this they need to have these skills*.

So Sandy first aims for the motivation (to trigger the interest) and then explores student's

prior knowledge, and skills, based on which she develops the inquiry lesson for learning the scientific process. She also considers about the skills the student may need, or to develop skills, during this inquiry process. Besides, Rachel mentioned the goal of her inquiry lesson as "*Learning is a more scientific processor what I think is a scientific method, how do scientists work and how reliable are the result from the experiment and even writing the experiment and report*".

Whereas, Valentine explains in the MYP science you need to see how science connects to our world and then how you communicate it. Students don't have to memorize content but they need to know how to apply the content literary or with literacy. Overall, all the three teachers aim for the process of inquiry of course, in different contexts, for example scientific process, to be able to apply the knowledge and communicate the results.

Content as goal

In inquiry, as contents are more curriculums based, the aim of the teacher for the end of the lesson is to know some topic or content mentioned in the curriculum.

As exemplified by the Jane's goals of the lesson "*I wanted them to learn to know what chromatography was, I wanted them to experience it so that they could physically see it because seeing is knowing, the third one was to connect, to its uses in the medical field. So there were three goals. The base goal for everyone, so the satisfactory student will be what is chromatography?"*

The goal of inquiry can be content or process or even both. Like mentioned by Jane, there were three inquiry goals: content knowledge, process knowledge's and the skill of applying and communicating the knowledge.

Whereas in the example mentioned by Rachel, the goal was content knowledge along with the process knowledge. "*Our unit of inquiry was about ISS space station and we look at why do they do experiment on the space station, what's the difference in gravity. All the students then designed an experiment themselves, that they thought they could do, if they are on the space station, and then each child in the class tested each other experiments to see if they were*

appropriate. So that was a big inquiry and that was more into the actual scientific process than the particular experiments and obviously other lots of information came out of that".

Furthermore, the teacher also focuses on developing skills along the way to achieve the goal of the lesson. Camilla narrates: "*We wanted to see actually that advancement in technology impacts our society and how do they do that. So that was the goal and the PowerPoint is a skill, how to use a PowerPoint instead of just standing up to give the presentation*".

Thus, it is again dependent on the teachers' personal perceptions and understanding and of course on the needs of students and curriculum, based on which they plan the goal of the inquiry as process or content or both.

Real world connection

The real world connection is about making a connection between scientific inquiry and the real world. Each teacher had her own perceptive on it, and had her own way to explain it. But almost all considered it to be very important. However, for some teachers it meant visualizing, and for others it meant connecting it to other people, parent speaker or parent involvement etc.

Below are three comments from the teachers' to clarify it.
Camilla invited a parent speaker who was an inventor to come and talk in the classroom for the unit Inventors. According to her, this gave the students a perception about "what it's like to be an inventor". An inventor was teaching them about the process of inventing and about his process. And he was teaching them that there are many ways of doing things and becoming an inventor.

Here we share glimpse of her example "*We had an inventor came to talk about how he got started as a child and how he had an idea when he was nine years old and the class is of 9-10 years old students. Because he said I started being an inventor when I was 9 years old and they (students) were oh…… ha ha. As till then the students imagined the inventor to be above 40 years. This inventor's talk not only gave them a real world connection, but also clarified many of their myths*".

Whereas, Jane described it as *"Make it real! I wanted them to experience it so that they could physically see it because "seeing is knowing*". *I like the students to be able see that how their experiments can be used in real life, and I like to be able to see that they are progressive and asking questions. As part of science for the unit, we are looking at test and procedure to check the diseases, and links it to the real world, and even give them science based experiments to do in the science lab and make it more visual*.

And the third teacher describes "*through the inquiry, they learn to be a scientist, I think, because although they might not officially know a scientific method or everything they are finding out about the world, but then in the weeks to come we use that information to make a more sensible world*". She thinks that the students start to apply the knowledge and learn the process of being a scientist.

So it's very personal what the teacher means by the real world connection or making it real and how he/she plans to achieve it in their lesson plan. But for sure, all the teachers want their students to connect their learning to the real world by any convenient means to make it more worthwhile and practical.

Cooperative learning

"Student learns from each other" although one of the teacher stressed on this issue but almost all believe it. A teacher explains how quick the students learn from each other about the new skills and techniques:

Camilla: *during their PowerPoint presentation, when one of student uses some different or new skills, other students went Oh! How you do that. It was one of the students Anna Catherine she had quiz at the end of her presentation. When you actually click on one of the buttons and then it would say that was wrong or right and some of the students had never seen that, and oh how do you do that? She answered, I learned it from my cousin and she started going around and showing them to their power point. So they are learning a lot from each other as well*.

Sharing knowledge is one of the most effective tools which not only helps the students to learn new concepts, but clarifies their concept or myths through the debates, arguments,

discussion among themselves. In inquiry-based learning where students have different activity in pairs, in groups and as a whole enhance their chance to share the ideas with each other.

Basic Knowledge

By the basic knowledge, the teacher means prior knowledge which can mean that a student has related knowledge to a topic or the knowledge they brought with them from the previous years. Some teachers referred to it as the student prior knowledge and some try to equip the student with basic knowledge needed to do the inquiry.

Jane: *I give them the basic, I give them the information first and I tell them what they are doing ok, from that we brainstorm, think, care, share and do a Venn diagram of different things so that we can work out what is the range of knowledge within the class*.

Besides, as explained by Sandy, after exploring the students prior knowledge, we find that the student knows this and to be able to do that, they need to know this and for this they need to have these skills.

Almost all the teachers start their lesson from students wondering and or we can say the teacher plan lesson to find the students prior knowledge based on which they build on their lesson depending on the students' needs. So the teachers considered the basic knowledge of the student as one of the key factors for student learning and their lesson planning.

The themes highlighted from the teachers' narration of their own inquiry example are presented by Figure 5 below. Figure 5 also presents the central aim of the teachers' inquiry example as curriculum (the central idea). The teachers have many other foci like the curriculum, real world connection, developing questioning mind, cooperate learning , and the real world connections with the student autonomy. In other words, to achieve the central aim and the content knowledge, teachers do consider many other aims along with student autonomy.

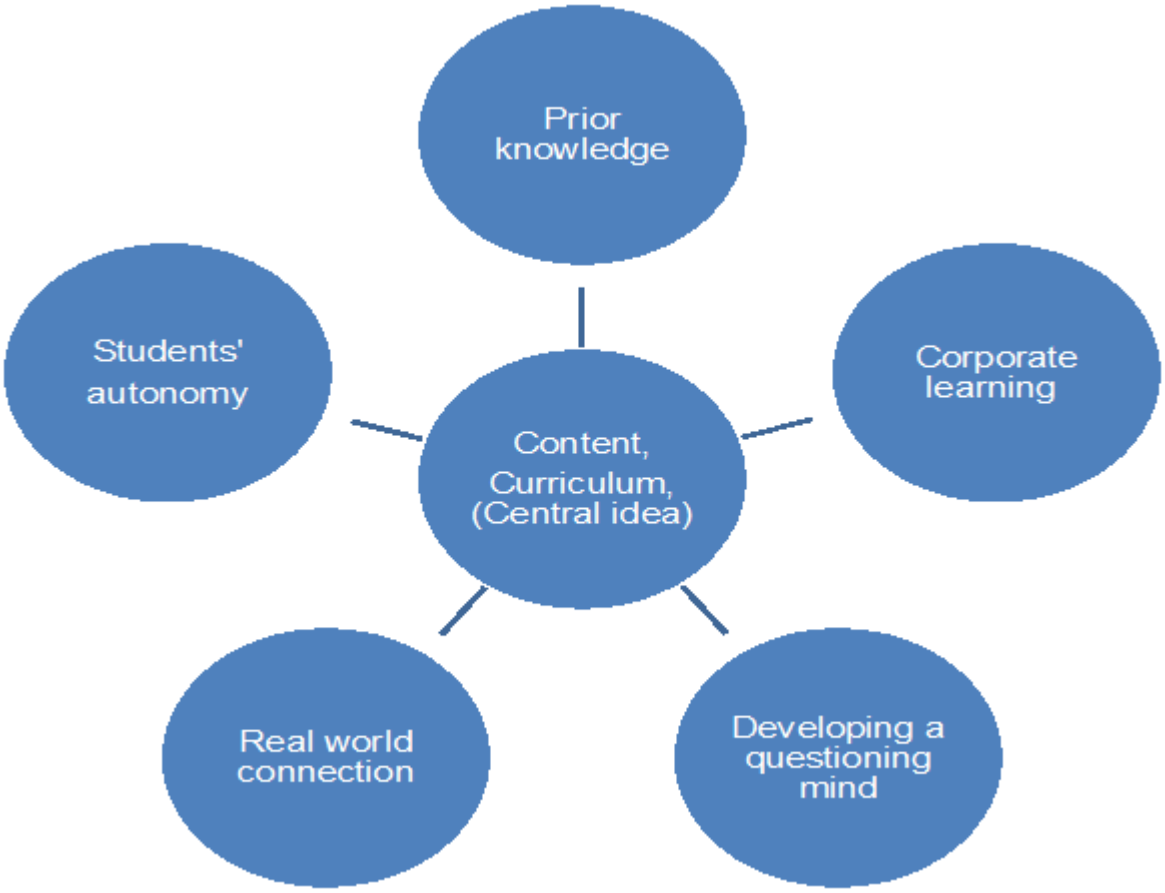

Figure 5: Themes highlighted from the teacher's inquiry example.

5.3. Teacher constraints, challenges and needs

Constraints the teachers face in planning or executing the inquiry lesson:

When I asked this question in the interview most of the teachers were very open, but one teacher took some time to open up for the question. She answered directly. I have no constraints in planning the inquiry “I really like teaching this way”. I think she took it in terms of expertise. But proceeding with it, I said "Some of the other teachers in the interview mentioned time etc. as one the constraints. This comment made open up to the question. The aim for this question in the interview was to find the challenges, problems they have in planning and executing the inquiry lesson so that in the future, the researchers and school authorities can consider it and support the teachers to overcome these challenges and not to evaluate the teachers' teaching practices.

Altogether, the teachers mentioned different constraints in planning and executing the inquiry, but most of them considered the time limitation and curriculum as the major concern and gave the similar comments like “It’s probably hard to get the balance with curriculum, inquiry and time". They also mentioned few other constraints and gave a very supportive comment to clarify their arguments which are being mentioned below.

I. Time: lack of time

Sandy's illustration suits very well here, *we always have million questions on the wondering cloud (a board with students’ inquiry sticker on it) and often we don’t get all of them covered and the unit is over. We have learned so much but there is a lack of time then you feel kind of bad as we have to move on to the next thing*.

All the teachers think time limitation many times a make a constraint in the inquiry. As in inquiry-based learning, sometimes the students have many creative ideas, or even sometimes they find that they could execute their inquiry in better way if they redo it, but they don’t have time.

II. Curriculum

Valentine illustrates, “*sometimes the curriculum can be very constraining because they are so specific to one detail, and I can refer to the English curriculum as I have worked with it in year 4. Students must know about Henry 8 and his eight wives instead of Tudors or what’s interesting in Tudors. Why do they have to know Henry 8 as a very important figure? There are also many other important figures to choose from during the Tudors. It's like, Why can’t someone learning about Tudors persuade Shakespeare, or the development of sport during that time or the development of music during that time. Whatever their interest might be, they could still learn about Tudors.*

The students still use similar skills, but by doing something which they are interested in, instead of what they been told, makes them feel interested. We must know all about the topic: it's not true, but you remember what you are interested in and the idea is that you learn how to process information read it and apply it! It should be a little bit more open and I guess to say more honest to the people not to a government or to a politician who doesn’t understand what education is about”.

So she thinks sometimes the curriculums are very specific that don't even leave the space for the inquiry.

III. Teacher role as facilitators

Most of the teacher struggle in between their role of facilitator or leader. Camilla shares "*My challenge is to keep students on track with my role as facilitator rather than jumping into the leadership role. Within it's always a challenge how much freedom they get and how much I direct them is a continuous struggle*". Whereas Rachel, it gets challenging to stick with the role of facilitator sometimes especially when student conversation or interest start to go off from the topic.

IV. Good inquiry question

To have an inquiry question that focuses on the curriculum (central idea), it's to be able to ask really good questions that can provoke inquiry and that can also lead the unit/lesson in the proper direction. Here proper direction means not being off from the unit, central idea or the aim of the unit. It's just to be on track to achieve the aim of the lesson. Here is the comment from Camilla, *I think another thing that can be challenging with inquiry-based learning is to be able to ask really good questions, it's very important, because, sometimes I want students to get to the answer without spoon feeding them, but provoke by asking good questions. So it's important that the inquiry questions have to be open just enough that can stimulate the thinking. It's not very important that students always have to have answers, or the correct answer. Because sometimes we teachers really gets like, we have to an answer, and there has to be an answer for everything, but maybe there is no answer, right now, or may be there could be different answers. The inquiry-based learning is motivated from the way of thinking that there can be different answers sometimes, different ways of thinking about something, different perspective*".

V. Designing authentic assessment

For authentic learning, to find the good assessing tool poses a challenge for many teachers, since learning is multi-directional. One of the teachers commented *"to design a proper assessment for these, authentic learning is a big challenge*". Although the teachers mention in

the interview that we get better at it every day and every time. But still they don't have much support for it.

VI. Motivation

According to Valentine, to engage the students, or to help them see, why I (student) have to do it is one of the major concerns. She is a MYP teacher and thinks students' motivation is the real challenge. Also, varied student interests can be very challenging sometimes. She explains: "*sometimes it is challenging to keep the student motivated when they chose the question or inquiry about which the teacher has no reference or clue. However, the teacher is available to guide the student with her basic skill like, where to find the information or how to process the information"*. Whereas, Jane commented *"it's very challenging to motivate the entire class with the different interest area at a time"*. The teacher has to have strong lesson planning for class with different abilities. Sometimes even a good lesson plan fails to motivate all the students. Additionally, Rachael mentioned that it gets challenging to motivate the student when in the middle of his/her inquiry process the student thinks that they didn't make good choice for the topic of inquiry investigation. In the above description, the teachers are talking about the motivation challenges in the different phrases of inquiry lessons.

VII. Assessing prior knowledge of the students

Assessing their prior knowledge is a major constraint, thinks Jane. She thinks that all the kids are different and have different abilities and needs and proper assessment of basic knowledge is a challenge. Not only Jane, but three other teachers also mentioned this.

Since all the teachers plan their lessons based on the students' prior knowledge and needs of the student groups, if this prior knowledge assessment activity is not considered important, sometimes the lesson can be a waste. For example, it can be too easy for the students or may be too challenging. In both situations it's a waste of time because if it too easy, the students don't learn anything new and if it's too challenging, it can have a negative effect on the students' motivation.

VIII. Physical size of the classroom

The physical size of the classroom was mentioned as one of the constraints by Rachel. She

explains that sometimes the students come up with the idea and wanted to do those wonderful things in the class but the due to narrowing of the material they can use in the class and resources available get the students frustrated. Many times the physical size the classroom also poses the constraints.

IX. Good search engine

Camilla gave a very sound example from her own inquiry lesson of how challenging it is to trust the search engine. She described that the students were asked to choose a simple invention and research about it and make a Power-point presentation. One student chose invention as pencil and found that it was invented in 1790 whereas the other student chose eraser and found that it was invented in 1770. After hearing to both the presentation Camilla was like, why will anyone invent the eraser before pencil? Among the two students' someone's information is not right but both the student found the information on the internet. So she said we have to be really careful what sites to use and is it the right information.

Summing up:

The main constraints mentioned by the teachers are limitation of time and curriculum, and having a good search engine. Other constraints mentioned by the teachers included: to be able to ask good inquiry questions, designing authentic assessment, student prior knowledge, motivating students, physical size of the classroom and limited resources.

Again, when it comes to the teachers' views on constraint, it depends on their own perception and experiences. Each teacher has their own perception of the constraints they face, although it's very student centered and context dependent. For example, if the PYP teacher got the chance to teach year 3 for two consecutive years and in the first year the teacher got a student with good prior knowledge and next year she got the student with less than average prior knowledge. In both years, although the teacher is the same but the context has changed. So are her constraints and consequently, her lesson plans, will also vary.

What needs do teachers see in developing inquiry-based teaching?

In this section, we are discussing the teachers' answer to the question about what should be done to support the teachers to use inquiry-based learning asked during the interview. The aim was to investigate the teachers' perception regarding how we can enhance the use of inquiry-

based learning. Analysis of the data unveiled that, according to most of the teachers, time for the collaborative planning is very important. A teacher commented on it as: "*we need time to plan together because, some of the best inquiry-based units are made by the teachers working collaboratively and if we don't have planning time we are just adding in the bits and pieces without really talking together and it's not as effective. So it's like if we could sit together and really plan it out and understand to execute it, the inquiry is more effective.*"

Three out of five teachers believed that Professional development (PD) courses are helpful while one teacher commented that she gained nothing from the PD course and commented against it saying "*they are very abstract, they must be more subject based and classroom based. Sharing a more concrete example during the course, could be more beneficial.*"

Most of the teachers wanted to have a good search engine. Rachel said "*it's hard for the students to find information on the internet that's at their level. There are some good websites, but it would be nice to know, some more websites for children that they get their answers, we have got a few., When I was teaching in Australia, I have got kids net.au so that's a search engine for the children. Usually, when the children have questions they wanted to research themselves on the internet, the information that comes up is a from NTNU or the research papers which are so far above their heads, I know there is lot out there, but lots of the information specially when we do unit on the water it's hard to have the things that are appropriate. So that will be really nice if you tell me some good websites.*

Additionally the Camilla comments *"I would really like to have the information support like for example school online in encyclopedia for the students to use where we know we can trust the information. That can really be helpful, so we need the resource".*

Almost all of the teachers voted for having good resources, like good trusted websites. Also to have the action researches like this present study. Camilla commented on it that, these types of research not only gets time and chance to reflect on their teaching but also leave a scope of improvement in the future. Besides, Valentine mentioned of having a mentor who can give feedbacks on their teaching practice. She commented *"Two heads are always better than one".*

CHAPTER 6. DISCUSSION AND CONCLUSION

Discussion

The discussion section has two parts: Part one discusses the results from the non-empirical study to shed light on “what inquiry means in the literature”? Besides, part two discusses the results from the empirical study and shed light on the central aim of the present study, “the teacher's views on inquiry-based learning and their personal inquiry based example” and even discusses the key concepts highlighted from the literature review and the teacher’s views on inquiry and their inquiry example. Additionally, it even discusses the teachers’ own descriptions of inquiry-based learning that contrasts to inquiry.

Section 1: What does inquiry mean in the literature?

A primary aim of this study was to shed light on “how the teachers conceptualize inquiry-based learning and their own inquiry practice. Before collecting the data, the researcher started with the literature review to explore the question “In what ways do various views of learning support inquiry approaches in Science teaching?” Although it is difficult to exactly trace the first appearance of inquiry instruction, based on the literature review, it is acknowledged that it was born out of the longstanding dialogue about the nature of learning and teaching (Cakir, 2008) in particular among Vygotsky, Piaget and Dewey. The literature review discloses that inquiry-based is a pedagogical strategy, emphasizes constructivist and social theories of learning. Constructivist approaches emphasize that knowledge is constructed through the active thinking, selective attention, organization of information, and integration with or replacement of existing knowledge; and that social interaction is necessary to create shared meaning. Therefore, an individual needs to be actively engaged both behaviorally and mentally in the learning process for learning to take place (Cakir, 2008; Mayer, 2004).

In particular, inquiry-based learning is motivated by the theories of Vygotsky, Piaget and Dewey (summarized in Doolittle & Camp, 1999). In other words, we can say that the work of theorists- Jean Piaget, Lev Vygotsky, and John Dewey was blended into the philosophy of learning known as constructivism which was then used to shape instructional materials. Specifically, in inquiry-based learning three perspectives of learning of Vygotsky, Piaget and Dewey overlap each other and are presented by the theoretical model in figure 2. Also

acknowledged by Mayer (2008), Dewey's broad theorizing of democracy's implications for schooling can be seen to integrate the research emphases of the two psychologists. Furthermore, Williams (2003) also states the connection between Dewey's knowledge of experience, Piaget's content of new knowledge and Vygotsky's cultural and social context. However, in this study the theoretical model (figure 2) was developed based on literature review which presents an overlap between the three theories. Particularly, Dewey's theory bridges or interlinks Vygotsky's and Piaget's theory of learning.

Since inquiry-based learning is an instructional model in which the learning process is always influenced by the environment which, it is also supported by the philosophy of Vygotsky's social cultural influence and Dewey's worthwhile experience. So, it's not a very easy task to express all its aspects in theory. This is illustrated by the theoretical model (figure 3) which highlights that inquiry-based instructional model is not based on a single theory, but is a blending of all the theories. The results from non-empirical sections of the study not only provided theoretical background about what inquiry means in literature but also made it convenient to understand and analyze the data collected through the interviews for the empirical study (Chapter 3). Moreover, it motivated us to think about the mediating factors that can influence inquiry-based teaching and learning process and provoked the research question 3 and 4 discussed in the next section.

Section 2: Teachers' views on inquiry and their inquiry examples

Results from the study indicate that teachers hold a broad view of what inquiry-based teaching means in science. Their overall conceptions can be described as very student-centered, where subject matter content appears to be less important. They value students' motivation, autonomy and development of curiosity and a questioning mind.

However, the teachers' examples of their own approaches to inquiry in the classroom gave a different direction to the results, where the focus is the subject matter to be taught. Their examples of inquiry practice are generally grounded in the curriculum. They talk about the central scientific idea of the unit they teach. From the examples they give, it is evident that the teachers plans the lessons based on the need of the curriculum and to achieve the central idea. All the teachers also consider other things like real world connection, students' prior knowledge, and how to explore new knowledge. They also hold much broader views of

inquiry than merely planning and doing experiments. If we compare the Figures 2 and 3, we see that the central focus of teacher describing inquiry-based learning is student autonomy whereas the central focus shifts to content, the central idea when they were describing their own inquiry example. Considering all the characteristics highlighted during the teacher's description of inquiry-based learning and their own inquiry example, it’s easy to perceive that the teachers have broader views on inquiry-based learning than just student-centered pedagogy.

Based on the literature review and the definition given by National Research Council (1996) and Linn et al, (2004) for inquiry-based learning the six key concepts of inquiry were highlighted and compared with themes highlighted by the teachers' views on inquiry-based learning and their own inquiry example is given in the table 1.

Table 1. Key concepts of inquiry-based learning themes highlighted from teachers' views on inquiry and their inquiry examples.

Based on the literature the six key concepts of inquiry highlighted	Themes highlighted from the teacher views on inquiry	Themes highlighted from the teachers own inquiry examples
Cognitive Development Social and cultural context Cooperative learning Authentic learning Authority of the problem and process Teacher role as facilitator	Motivation Making connections Developing a questioning mind Students' freedom Student ownership	Central idea Goal: Content vs. process Real world connection Learning from each other (cooperative learning). Basic Knowledge

It is quite interesting to note that all the teachers used the key concepts highlighted from the literature review when they were describing their views on inquiry or their inquiry example. However, the key concepts highlighted from the literature (see 1st column in table 1) didn't

mention the curriculum or the content similar to the teachers' views on inquiry learning (see 2nd column in table 1). In other words, we can say that, both literature and the teachers' view on inquiry-based learning, the key concept the curriculum/content were not highlighted. On the contrary, when the teacher described their own inquiry example, they focus on curriculum and content knowledge (see 3rd column in Table 1). This shows that when the teachers describe the inquiry, they considered inquiry as more student-centered which is very similar to common literature insight about inquiry as very student centered. However it's just the outer essence of inquiry and very general or basic thinking that inquiry-based learning is student centered pedagogy. Whereas, the teachers' own inquiry approaches examples in the classroom provided more practical aspects of inquiry, where insights into the inner core of the inquiry leads to many other key concepts that are more important than student autonomy alone.

Furthermore, Figure 6 shows the connection of the key concepts highlighted from the teachers' views of Inquiry to the theoretical model proposed from the literature review. The theoretical model (Figure 2) was to show the relation between the three theories of Vygotsky, Piaget and Dewey. Undoubtedly, teacher views on inquiry-based learning resulted to be very student centered and closer to Piaget's cognitive learning theory, whereas the teacher descriptions of their own inquiry lesson highlights Dewey's content knowledge, authentic learning, as well as Vygotsky's learning theory with social and cultural context. Henceforth, this relation of key concept highlighted from the teachers' views on Inquiry and learning theory not only gives us the insight that inquiry-based learning instruction is a blend of the three learning theories – Dewey's, Piaget's and Vygotsky's but also justifies my theoretical model. Furthermore, the overlap of these theories mentioned in the theoretical model is even witnessed in the teacher views in the case study. For instance, the teacher's role as facilitator is one of the key concepts in both learning theories of Dewey's and Piaget's whereas corporate learning is one of the key concepts in both the learning theories of Dewey's and the Vygotsky's (see chapter 2).

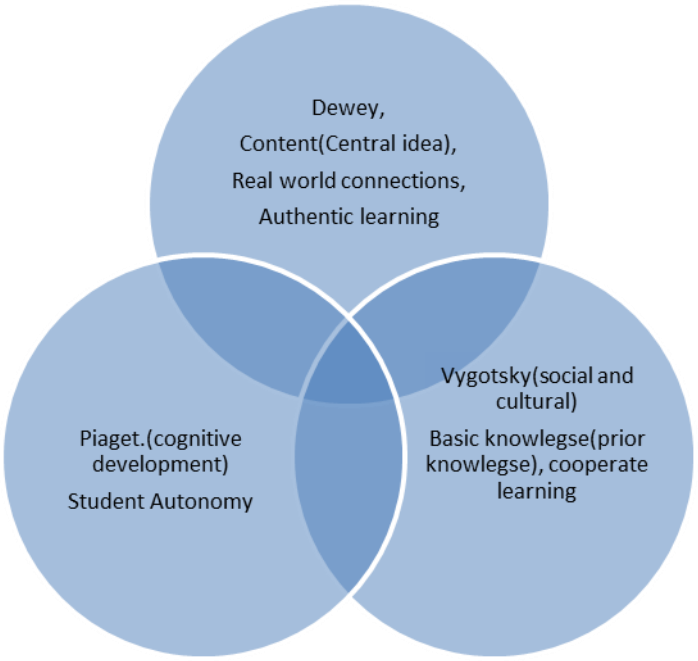

Figure 6: Theoretical model and key concepts highlighted from the teacher views on inquiry-based learning and their example.

Teachers' own descriptions of inquiry-based learning: Contrasts to Inquiry

Three out of five teachers call themselves old fashioned or traditional teachers. As illustrated/expressed by Camilla *"I am old fashioned enough that I do still try to cover the basic skill and keep that going and on the surface have this all other stuffs going on, the inquiry"*. Even Jane said that *"I give them the basic, I give them the information first and tell them what they are doing ok, from that we brainstorm, think, care, share and do a Venn diagram of different things so that we can work it out"* where she provides the basic information before starting the inquiry. In fact, Rachel stated that we all are traditional teachers if we considered that we used the science lab. Although teachers applaud inquiry, they also talk about using traditional or old fashioned teaching. That the teachers think of traditional teaching as an aide for inquiry surprises me! Moreover it gives a reason to think that inquiry by itself is not self-sufficient or is the traditional teaching different from the inquiry? Although all the teacher are different and inspired by different learning theory and use the different ways of teaching so it will be quite unfair to say that old or traditional way of teaching was different from inquiry. However the modern schools emphasize on one teaching theory, for example; The International Baccalaureate IB has a curriculum framework with a

powerful emphasis on inquiry-based learning. Also, the teachers get professional training to understand and implement this framework.

Furthermore, Rachel explains that in a classroom, open inquiry is impossible "*because we have this unit of inquiry that we are imposing on the children. We even have a curriculum that has to be covered. On the contrary, if it was total inquiry, we have to just let the student to discover and learn themselves. In preschool, we encourage children's natural inquiry where we let them just be the inquirers, whereas we do more structured inquiry in school, because we impose a curriculum on the student. Nevertheless in that curriculum we do let them inquire*.

So she thinks open inquiry is possible in preschool and it's almost impossible in the school as we have the curriculum to cover in the school. Which again leaves room to think, do we have only structured inquiry in the school? Is it the complete form of inquiry?

The limitations of the study

The researcher believes that many factors may limit the ability of this study to synthesize knowledge and make claims from the available data, such as the method used to collect or the data analysis. Although there is validity in qualitative study design, the case study is best fitted for the research question of this study and for data collection. This study fully acknowledges that with different models of study design, we could have possibly come up with different conclusions. Additionally, the research was done in only one international school with a limited number of teachers, and the personal bias of the interview constitutes another limitation in this study. Moreover the conclusion is drawn from the teachers' perception that it would have been more reliable if the researcher was present in their lesson. The researcher works part-time at the school which created a friendly atmosphere. According to the researcher's knowledge and belief, the teachers were very open to answer any question. Like, the teachers agreed that the principal provided them with the material related to inquiry, but they get less time to read, and one of the teachers commented that they are repetitive and boring whereas another one said that it's all academic articles and are not related to our lesson or lesson planning. These comments make me feel that they were very free to express their feelings to me that I will follow the ethics of confidentiality. But the researcher being the staff member can also be considered as a limitation of this study since being colleagues, they may

hide some facts or controversial issues.

Conclusion

In this case study if the teachers were not asked to describe their own example, the findings would have shown that teachers care only about student motivation and autonomy and not about the scientific learning as prescribed by the curriculum. From the theoretical point of view, it would have shown that the inquiry-based theory is influenced only by Piaget cognitive learning theory. This means that care should be taken in order to avoid misinterpreting the results from teachers' interviews.

When we spoke to the teachers about their views on other way of teaching than inquiry, although teachers applaud inquiry, few of them also talk about using traditional or old fashioned teaching. Teachers' comments leave a reason to think that whether inquiry-based learning is different from traditional teaching. Otherwise, why would they consider themselves to be old fashioned teachers?

When it comes to constraints that a teacher faces in designing or implementing an inquiry lesson, it's more individualized. The major concerns for all of them are time limitations, curriculum, and having a good search engine. Few others concern are to be able to ask good inquiry questions, designing authentic assessment, students' prior knowledge, motivating students, physical size of the classroom and limited resources. The researchers, curriculum leaders and the professional development leaders can thus consider these constraints that the teachers face and try to help them overcome these. Researchers can also help in developing some search engine aimed at young children and readily available for all.

Results show that the teachers considered collaborative planning as more supportive for enacting inquiry-based learning from the professional development courses. They believe that collaborative planning helps in cross curricular activities. Additionally, it saves them time and also avoids the topic from being repetitive for the students. Moreover, teachers in the same school are aware of the environment, cultural factors and the resources available so that the inquiry lessons planned together are more feasible. The brief prepared by Caven et al.(2013) on collaborative planning suggests that "the availability of collaborative planning time also

offers rich potential for improving invaluable instruction, developing a professional learning culture amongst staff, and ultimately, maximizing student learning" (Page,7). Darling-Hammond et al. (2009) stated one of the key findings in their Status Report on Teacher Development as "Collaborative approaches to professional learning can promote school changes that extends beyond individual classrooms. When all teachers in a school learn together, all students in the school benefit". Thus, the school authorities should consider having sufficient collaborative planning time in the teachers' schedule and also having a mentor to support the teachers in improving their teaching practice through qualitative feedbacks.

Furthermore, teachers expect more concrete examples in the workshop than only abstract information from the professional development courses. So, the professional development leaders must consider teachers' feedback for improvement of these courses. As an educational researcher, professional development leaders aim to support the teachers to improve their teaching and learning practices. However, it is equally important to consider the teachers' views to increase the success of any project or workshop. Additionally, research committees must promote this type of action research in the school not only to support the teachers but also improve the teaching practice as this type of a research project can prove to be a good link between the teachers, the researchers and the professional development leaders.

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APPENDIX 1: INTERVIEW GUIDE

What is your educational background? (Which teacher training do you have) ?

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How often do you have professional development course? (about inquiry/ teaching methods)

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How many years of experience do you have in teaching science?

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Describe an example from your own teaching practice which constituted inquiry-oriented approach according to you?

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What is the goal of the lesson in terms of student learning?

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How do the students respond?

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What were their challenges?

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…… ……...

What do they like about it, what do they learn?

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…… .....

How often do you design this type of lesson plan for your units?

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What is your personal view on inquiry based learning?

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What are the constraints you face in designing or executing an inquiry lesson?

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What should be done to support teachers for the inquiry based learning?

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APPENDIX 2: ESERA PAPER

TEACHER'S VIEWS ON INQUIRY BASED LEARNING AND THEIR EXAMPLES OF INQUIRY-ORIENTED APPROACHES

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Abstract: This paper reports a study of teachers' perspectives on inquiry-oriented approaches and how they conceptualize it. Five teachers from an international school were interviewed. They were asked to describe how they interpret inquiry-based teaching, and to give examples of their own teaching practice in line with inquiry- oriented teaching. The results from the inductive analysis show that teachers considered student autonomy as the most prominent in their perception of inquiry-based approaches to science teaching, but their example revealed that they consider content knowledge from curriculum, and how this connects to the real world as equally important as student autonomy.

Keywords: teachers views, inquiry-based teaching, student autonomy

BACKGROUND

Inquiry-based learning is seen as a way forward in science education worldwide (see e.g. Rocard, et al., 2007). A reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods may increase children's and students' interest and attainment levels while at the same time stimulating teacher motivation. Many studies conducted on middle and high school students have concluded that inquiry-based science activities have positive effects on students' achievement in science in terms of cognitive development; laboratory skills, science process skills, and understanding of science knowledge as a whole (Gibson & Chase, 2002).

Inquiry Based Learning (IBL) is seen as a student centered pedagogy, which is different from the memorizing facts of traditional approach. In inquiry-based learning, students explore and build new knowledge based on their previous knowledge with the support of teachers, technology and peers. An inquiry can have broad and narrow conceptions, depending on the

teacher's personal beliefs and goals. In the US, the National Research Council describes an inquiry as a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (National Research Council, 1996, p 23). Linn, Davis and Bell, (2004) define inquiry as "the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers and forming coherent arguments". These descriptions show that inquiry-based teaching and learning is open to a diversity of interpretations. In schools, it will depend on the teacher's personal beliefs and goals, as the teachers' views of learning and teaching will shape their interpretations of curricular and instructional approaches (Crawford, 2007). It is therefore important to take teachers' views into account for enhancing opportunities to adopt reforms and to bring them into the classroom. Additionally, there are many mediating factors that serve to influence a teacher's ability to play out his or her beliefs in practice. Thus, it is important to try to understand a teacher's beliefs, and in what ways beliefs are enacted in actual teaching practice (Bryan, 2003). As noted by Keys and Bryan (2001), we have little knowledge of teachers' views about the goals and purposes of inquiry. The aim of the present study was therefore to explore teachers' views on inquiry-based approaches to science teaching and to understand how these views are realized in concrete teaching practice.

RESEARCH QUESTIONS

What are the teachers' personal views on the content and aims of inquiry-based science teaching?

How do these views relate to what they consider to be inquiry-oriented approaches from their own teaching practice?

THE CASE

The study is undertaken as a case study of five teachers working at a Trondheim International School (THIS) in Norway. The school is an International Baccalaureate (IB) School where

inquiry-based teaching approaches form part of the school policy. All teachers were therefore familiar with inquiry-based approaches. The teachers were of different nationalities and had their training in science as well as teacher training from various countries. All the five teachers have either bachelor of education or master in education and two of them have a background in science. Their teaching experience in science ranged from 11 to 30 years.

RESEARCH METHODS

Data were collected during the academic year 2011-2012 from the Primary Years Program (PYP, age 6-11 years) and Middle Years Program (MYP, age 12-15 years) at the International School. The PYP teachers teach science as the integrated subject together with other subjects. Data were gathered by means of audio recorded semi-structured interviews. In the interviews, teachers were asked to describe their personal conception of inquiry-based teaching, and then to give an example from their own teaching practice that they believed constituted inquiry-oriented teaching. The questions were open-ended in order to allow for the teachers to contribute with as much detailed information as possible, and provide for the researcher to ask probing questions as a means of follow-up. The sequences of the questions were usually dependent on the flow of conversation. Predefined questions in the interview guide included questions on the teacher's view on inquiry-based teaching approaches in general, and on a concrete lesson from their practice they considered to be a concrete example of inquiry-based teaching. For this example, teachers were asked to describe what the goals were how students responded, what they learnt and what their challenges were. The teacher's experiences with professional development and constraints in performing inquiry-based teaching and how they could be overcome were also addressed in the interview.

Interviews were fully transcribed for analysis. To organize and manage the data the software ATLAS.ti Version 4.2 was used. Codes were developed by studying the transcripts repeatedly and considering possible meanings and how these fitted with developing themes across the individual teachers. Summaries of each code were constructed and then compared and refined across the informants.

RESULTS

In the interview the teachers were asked about their personal views on inquiry-based learning. In the teachers' responses, we were looking for their understanding of inquiry- based approaches and the issues they considered most important. The study revealed that each teacher applaud inquiry and consider it very important which is explicated from their comments such as "*I love it*", "*it's a natural way to learn*" and "*it suits my philosophy*". Analysis of data on the teachers' views on inquiry resulted in five broad themes. All the themes were represented in how several teachers described their view on inquiry-based teaching. The themes are presented below, exemplified by one quotation for each theme.

Motivation

Teachers see inquiry-based approaches as motivating for the students and a way to get them involved in science.

Camilla: "*I think it's very good, especially for the students who have low motivation. It's a way to get them involved, take some ownership, and really go in a direction which is interesting for them.*"

Making Connections

Teachers see inquiry-based learning as a way of connecting elements of knowledge in holistic and meaningful ways.

Valentine: "I think it's a natural way to learn, you learn when you like, and you intensely make other connection to thing in your brain. Inquiry is based on people pursuing in a way that you make more connections, synaptic connections."

Developing a questioning mind

Teachers see inquiry-based learning as a way of developing students' curiosity and will to learn.

Jane: "*It is extremely important to keep the questioning mind of a toddler still when you are a teenager*".

Students' freedom

Teachers emphasize students' freedom in teaching activities, and see inquiry-based teaching approaches as a way of transferring control from the teacher to the students.

Rachel: "*In an inquiry class, students are given freedom to make decisions and the teachers trust the students*."

Student ownership

Teachers see the openness of inquiry as a way of developing students' responsibility and to give them ownership to their results.

Sandy: "*Children grow and take responsibility for their learning. I see them excited about something that they come up with, connecting it to the world and sharing their new knowledge and their discoveries. It is really valuable*".

Summed up we can conclude that teachers value inquiry-based teaching as it is good for low motivated students, it gets students involved, let them explore according to their interest and make connections. It also develops students' questioning mind, freedom to make decisions and their ownership of learning. This indicates that teachers value inquiry-based teaching as very student-centered teaching where student autonomy is considered the most important.

This could signal that teachers pay less attention to students' subject learning in the inquiry-based activities. However, when we analyzed the example described by teachers of their own teaching practice it is found that they do consider many other aims when undertaking an inquiry lesson. Teachers' often refer to the "Unit of inquiry" and the "central idea". The unit of inquiry is the topic given in the curriculum and the central idea is the focus of the unit.

In the following, we present three examples of teachers' descriptions of their concrete approach to inquiry in their teaching.

Camilla's example: Inventors

Camilla is a PYP teacher describes the inquiry example as following. Unit of inquiry: Inventor

Central idea: Technology has changed the world of work and leisure.

Camilla's starting task was to let students draw a simple sketch of what they think an inventor looks like, and then what kind of person do you have to be, to be an inventor.

She explains: "*I wanted to see what they believe an inventor is and do they think they could be inventors. We also had really exploring the central idea, that's very important to do in the beginning. We did Venn diagrams: What technology has changed the work, what technology has changed leisure? And which ones will go in the middle for both. We had an inventor came in talk about how he got started as a child at the age of nine, that's the student's age. This also gives another prospective of what's like to be an inventor. He was teaching them the process of inventing, or his process and teaching them there is not only one way. And from that they were asked to research a simple invention that has change the world of work or leisure or both. And they were going to investigate and gather research and make a PowerPoint*

presentation."

Camilla shows how she develops the inquiry from students' prior knowledge, to connecting to the real world, to applying knowledge and gets to new knowledge as the process of inquiry to achieve the final product of the inquiry the curriculum.

Jane's example: Diseases

Jane is the PYP teacher her Inquiry is as follows. Unit of inquiry: Diseases.

Central idea: Although people have discovered many ways of preventing and coping with diseases, the pursuit of preventing, curing and supporting people with various illnesses continues through the work of organizations.

Jane explains: "*We at the moment doing a unit of inquiry around diseases, and the illness and suffering that occur from it. As part of science we are looking at tests and procedure to check whether you have that disease. This links it to the real world; it links it our unit of inquiry and gives us some science-based experiment in the science lab. Today I am going to talk about chromatography. It's something which is used a lot in outside world from the genetics all the way down to the urinary test. I provide kids with information through a video which shows how the test is done so that they see what is happening. We use their background knowledge of acid and bases and how different chemicals would have different shades within the color, pulls it together and we go down to the lab where we do a simple experiment with the mark pens so that they can physically see and work out what it is. I give them the basic information first and I tell them what they are doing ok. From that we brainstorm, think, care, and share and do Venn diagram of different things so that we can work out the range of knowledge within the class. From there we do inquiry into treatments. Then they go off, they find the treatment themselves, they came back and told me all sorts of different treatment. They use researching skills on the internet, they use their parents for knowledge and they use firsthand experience. But when you have to take it down to the science lab you have sort of, I feel you have to funnel it back down to something small. So they can physically do it. But then they make the connections back out from the funnel so it's like a little tree*."

Jane's example had the same phrases of prior knowledge, connecting to the real world, exploring and applying to get new knowledge. She let the students wonder and help them develop their conceptions. When it comes to hands-on activity, she helps them to linking it to some simpler things which are physically possible in the lab, and that aims at achieving the content knowledge.

Valentine's example: Chemical Reactions

Valentine is the MYP teacher she gave an example as follows. Unit of inquiry: Chemical Reaction.

Central idea/unit question: What would the world be like without chemical reaction?

Valentine explains: "*The inquiry that I had was investigation. I had them look into chemical reactions. They had to name chemical reactions; they had to find out about - where it occurs, what the name of it is, what the starting product is and what the end product is after the reaction. They have to explore why it happens and where it happens.What is the chemical reaction for, do humans use this chemical reaction for any specific reason and then also explore what would the world be like without it. So there are lots and lots of question just based on chemical reactions and the idea as in this example is it they see chemical reaction in science connection to a world which was the main thing.Then how they communicate this, during the process I was available with resources and with my knowledge. It wasn't necessary assessing knowledge. I was assessing how they could find things so it's a very open question or open idea with lots of questions attached to it. They could explore different ways and they needn't have to answer all questions. It was open enough for them to explore things in their own pace and for their interest. So it is inquiry because they had to present something in their interest range, and then what I was looking at was the links they make.*"

Valentine let the student explore according to their interest, she stresses that students can make different links to the topic depending on the interest and keep them motivated for the learning. She comments that in science you need to see how science connects to our world and then how you communicate it. They don't have to memorize content; they need to know how to apply the content literary or with literacy.

DISCUSSION AND CONCLUSION

The results indicate that teachers hold a broad view of what inquiry-based teaching in science means. Their overall conceptions can be described as very student-centered, where subject matter content appears as less important. They value students' motivation, autonomy and development of curiosity and a questioning mind.

However, the teachers' examples of their own approaches to inquiry in the classroom gave a

different direction to the results, and the subject matter to be taught is here more in focus. Their examples of inquiry practice are generally grounded in the curriculum. They talk about the central scientific idea of the unit they teach. From the examples they give, it is evident that the teacher plans the lesson based on the need of curriculum and to achieve the central idea. All the teachers also consider other things like real world connection, students' prior knowledge, and how to explore new knowledge. They also hold much broader views of inquiry than merely planning and doing experiments.

If the teachers were not asked to describe the example, the findings would have shown that teacher care only about student motivation and autonomy and not about the scientific learning as prescribed by the curriculum. This means that care should be taken in order to not misinterpret results from teacher interviews.

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