Enhancing Students’ Motivation towards School Science with an Inquiry-Based Site Visit Teaching Sequence: A Design-Based Research Approach
Anni Loukomies

Enhancing Students’ Motivation towards School Science with an Inquiry-Based Site Visit Teaching Sequence: A Design-Based Research Approach

Academic Dissertation to be publicly discussed by due permission of the Faculty of Behavioural Sciences at the University of Helsinki, in Small Festival Hall of the university main building, Fabianinkatu 33, on Saturday, December 14th 2013, at 12 o’clock
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ISBN 978-952-10-7881-1 (nid)
ISSN 1799-2508
Unigrafia
2013
Abstract

An inquiry-based site visit teaching sequence for school science was designed in co-operation with researchers and science teachers, according to the principles of Design Based Research (DBR). Out-of-school industry site visits were central in the design. Theory-based conjectures arising from the literature on motivation, interest and inquiry-based science teaching (IBST) were embodied in the design solution, and these embodied conjectures were studied in order to uncover the aspects of the design related to students’ motivation and interest. The design solution was researched throughout the process. The aim of the design was to generate a phenomenon to be investigated in the research stage. The aim of the research was to clarify which particular aspects of the design have appealed particular students and enhanced their motivation and interest, and what scientific content students have learnt within the project.

In this research report, the iterative design process with several implementations of the site visit teaching sequence, research methodology and the results that emerged, are considered.

The design process took place in the years 2007–2009. A pilot cycle, two implementation-refinement cycles and a final trial were conducted. Lower secondary school students (age 14–15) participated in the cycles. Data were collected using a mixed-methods approach. The students’ experiences of school science were mapped with the Evaluation of Science Inquiry Activities Questionnaire (ESIAQ) before and after the implementations. The students’ Self-determination theory (SDT) based motivation orientations were examined using the Academic Motivation Questionnaire (AMQ) before the implementations. Both questionnaires are based on SDT. Students with different motivational profiles and their teachers were interviewed using a semi-structured interview protocol. The interviews were analysed by employing a theory-driven content analysis approach. The students’ representations of the scientific content of the sequence were examined by comparing the informal mind maps they constructed before and after the sequence, and with interviews.

The results of the research reveal that a teaching sequence that combines inquiry activities, industry site visits and writing tasks contains the potential to enhance students’ feeling of relevance of their science studies and promote motivation and interest in school science. When asked about the most motivating aspects of the teaching sequence, students emphasised different aspects depending on their motivational profile. Students with an autonomous motivation orientation emphasised the support for their independent planning and decision making and support
for their personal interest, whereas amotivated students reported an increase in their feeling of the relevance of studying. The results show that students in science classes value different aspects of science learning based on their motivational profile. The site visit teaching sequence offers science teachers an appropriate way of differentiating teaching according to students’ different needs.

Because the research problems of this research project are multifaceted, concerning the design process, students’ motivation and students’ learning of the scientific content of the sequence, the problems of design, motivation and learning are reported in three different sub-studies, each containing specific research questions, data analysis and discussion.

*Keywords:* motivation orientation, industry site visit, design-based research, inquiry-based science teaching
Luonnontieteiden opiskelumotivaation tukeminen yritysvierailujen avulla: Kehittämistutkimus lähestymistapana

Anni Loukomies

Tiivistelmä


Väitöskirjassa on raportoitu eri opintokäyntiin liittyvät näkökulmat omissa alatutkimuksissaan, joista jokaisessa on erilliset tutkimuskysymykset, aineiston analyysi ja pohdinta.

Avainsanat: motivaatiosuuntaus, yritysvierailu, kehittämistutkimus, tutkimuksellinen luonnontieteiden opettaminen
Acknowledgements

I have had the best supervisors one can imagine. Professor Jari Lavonen, you have had trust in me since the very beginning of my doctoral studies, even in situations that I have not trusted myself very much. You have organised so many opportunities to co-operate with the finest experts in the field of science education and to participate in international conferences. Your feedback has helped me to proceed, and you have always had time for conversations. Docent Kalle Juuti, you have always been willing to consider the problematic aspects of my work that I have faced, and you have introduced me new perspectives to aspects with which I was struggling. Jari and Kalle, without your friendly support I would not be at this point now. It has also been nice to work with you two when designing the teaching sequence together.

I sincerely thank the pre-evaluators of my work, professor emerita Maija Ahtee and professor Harry Silfverberg. Your critics and comments have been valuable when I have been finalising the thesis.

I am also very grateful to associate professor Lars Brian Krogh for agreeing to be my opponent.

This design research project has been conducted as a part of the Materials Science project and S-Team project of the European Union. International collaboration has been central in these projects. I am thankful for the opportunity to work with the adorable Greek colleagues, associate professor Dimitrios Pnevmatikos, assistant professor Anna Spyrtou and professor Petros Kariotoglou, when implementing this design in Florina, Greece. Your perspective and expertise have been very valuable to me. I also want to thank professor emeritus Veijo Meisalo who has been developing the first models of the industry site visit sequence in 1980’s and whose valuable comments have been helpful when revising the present version, docent Reijo Byman for his help with motivation related issues, and lecturer Jarkko Lampiselkä, whose expertise in chemistry has been important when designing and revising the teaching sequence. I also want to thank colleagues at the Department of Teacher Education for the nice collaboration and conversations.

I thank the Finnish Concordia Fund and the Finnish Cultural Foundation for the grants that were awarded to me for completing the project.

During my doctoral studies I have been working as a teacher in Aurinkolahti comprehensive school in Helsinki and as a lecturer in the Viikki Teacher Training school of the Helsinki University. The headmasters of these schools, Leena Sipponen in Aurinkolahti and docent Jyrki Loima, Pirkko Manner and Kimmo Koskinen in Viikki have been favorable to my project. Leena, Jyrki, Pirkko and Kimmo, I thank you for your help when organising time for my project.
I also thank all my dear colleagues in Viikki school for your interest in my project, and especially Dr Reetta Niemi and Dr Katiarina Stenberg, for your support when finalising my work and reflecting my thoughts and emotions concerning it.

I sincerely thank all the teachers and students who have been willing to test and evaluate the teaching sequence that has been designed in this project. I also thank all my pupils that I have been teaching during the years of this project. You have helped me to keep my feet on the ground.

I thank my parents Marjatta and Kari Salmela, for your support during my studies, babysitting and everything one can imagine. No matter the problem, everything has always worked out. I also thank my mother-in-law Annukka Kavanne, whose help has been priceless and with whom I have had interesting conversations related to many aspects of education. I also want to thank my relatives who have been expressed their support to me during this project.

I thank my marvellous sister Maija Itkonen for being an embodiment of the attitude that nothing is impossible, and that if you have an idea, you will always find means to realise it. I also thank all my dear friends who have had interest in my project. Especially I want to thank my most important friend Jonna Laitonen who has gone with me all the way since the day we went to the first grade 31 years ago.

I thank my four-legged friends Elsa and Kerttu for helping me to understand the importance of coherence and unambiguousness in instruction, and for taking me away from my computer and out for a walk.

I am honoured to be a mother of two precious children. Lempi and Sisu, I love you so much and I am so proud of you. I am grateful for the opportunity to be a part of your lives. I am also so grateful to my precious husband Tuomo, for supporting me in all my undertakings and for co-operation when conducting the most important task there is, supporting our children in their development and growth. Tuomo, Lempi and Sisu, I dedicate this work to you.

10.11.2013

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1 Introduction

Students’ motivation and interest in science studies has been a widely discussed concern within science education research and in policy papers (e.g., European Union [EU], 2004, 2005; Osborne, 2008; Osborne, Simon, & Collins, 2003). Although students find science-related issues interesting and important in general, many of them do not choose science courses at school and do not see themselves potentially choosing a scientific career in their future; even if they are interested in science, they may be even more interested in some other subjects, which prevents them from choosing a career in the field of science (Lavonen, Gedrovics, Byman, Meisalo, Juuti & Uitto, 2008; Osborne, 2008; Tytler, Osborne, Williams, Tytler & Cripps, 2008; Woolnough, 1996). Students may hold negative stereotypical and one-sided images about science-related occupations, and thus consider these occupations not worth pursuing (Scherz & Oren, 2006; Schreiner & Sjöberg, 2005; for a detailed overview of students’ images of scientists, see Christidou, 2011), or they, especially girls, are not introduced to appealing role models to follow (Lavonen et al., 2008). The concern about the decreasing number of students who are personally interested in science and technology in order to later pursue a scientific career also emerges in educational policy papers. In fact, it is considered one of the most critical issues in education and the labour market within Europe and the Organisation for Economic Co-operation and Development (OECD) (EU, 2004, 2005; OECD, 2008).

The reason for the lack of students’ interest and motivation to invest in science studies is worth considering. After reviewing the Program for International Student Assessment (PISA) 2006 results, Bybee and McRae (2011) argue that students’ interest in science topics decreases as the topic moves further away from personal experience and immediate relevance to students’ own lives. Students may not see the connection between their science studies at school and their own life goals. Following this argument, increasing students’ feeling of the relevance of their studies and revealing to them the connection between science studies at school and real-world applications of the same phenomena and career possibilities in technology industries should increase their interest. Furthermore, the OECD (2008) recommends that students should have access to realistic information about science and technology (S&T) and careers in the field through direct contacts with professionals. Tytler, Symington, and Smith (2010) share this view as they argue that partnerships between schools and industrial organisations are important for local-level curriculum development if the aim is to have an impact on students’
interests. In their literature review, Lavonen et al. (2008) claim that role models met during visits may be important when students are planning their future.

The aspect that makes the problem of interest in and motivation for science learning even more complex is that all students are not alike, and similar procedures do not appeal to everybody. The fact that there are differences between students’ motivation orientations is, of course, obvious to anybody that has ever worked as a teacher, but in this study the consequences of students’ different motivational profiles are explicated systematically in the context of science education. To conceptualise motivation, after having considered the multifaceted field of motivational science (e.g. Pintrich, 2003), it was decided to follow the self-determination theory of motivation (SDT) fashioned by Edward Deci and Richard Ryan (2002). This theory takes into account the qualitative differences in motivation orientations, which is an important factor in classroom implications. Students’ different motivational profiles bring a thought-provoking aspect to the dynamic system of a classroom. What works with some students may not be the optimal means for others. The contemporary curriculum for basic education emphasises considering students’ individual needs and preconditions (see the [Finnish] Amendments and Additions to the National Core Curriculum for Basic Education [AANCCBE], 2011), and this challenge has to be taken seriously in science education as well.

Is it possible to design a teaching sequence for school science that benefits all students despite their different motivational profiles and, if so, what are the essential aspects of such a sequence? The contribution of this research to this multifaceted problem of students’ low motivation and interest in investing their cognitive capacity in science studies employs out-of-school industry site visits in the context of school science. In this framework, industry site visits are seen as a means of improving students’ understanding of the varied career possibilities within the field of science and of the importance of choosing science courses at school if later pursuing a scientific career. The philosophy of inquiry-based science teaching (IBST) that is described in more detail in Chapter 5 constitutes the grounds for the design, and the design solution offers science teachers means of optimising the social context of the learning situation in order to enable students’ inner potential to flourish, while taking the students’ existing motivational profiles into account. Based on the literature review, differences in students’ motivational profiles are taken for granted in this research, and therefore, instead of examining the motivation and interest development of the entire group, it was deemed more relevant to consider which aspects of a certain teaching sequence appeal to certain students with particular motivation orientations.
Various classroom phenomena related to learning, interactions, motivation, and interest represent themselves more as complex and dynamic systems than predictable causal relations between teachers’ teaching and students’ learning. Examining aspects of learning and education as isolated variables in artificial laboratory settings may lead, first of all, to an incomplete or false understanding of teaching and learning in an authentic setting and, secondly, to results that may not have impact on real educational problems (Barab & Squire, 2004). Therefore, it seemed unrealistic and unproductive to conduct a strictly-controlled intervention and then only investigate its influence experimentally. However, problems also emerge from the authentic context because there may be variables that cannot be controlled. As a result of considerations about the research design, trustworthiness, and applicability of the results, a design-based research approach (The Design-Based Research Collective [DBRC], 2003) was chosen for the methodology of this study. In design-based research (DBR), the developmental work of a pedagogical solution (artefact) and scrutiny of its effectiveness and yield of novel knowledge are intertwined throughout the process. In fact, in this research report, describing the design process and tracking the decisions made during it are together more important than either the process or the results on their own.

As the imperative of the research project has been enhancing and improving students’ motivation for and interest in science studies and possible science, technology, engineering, and mathematics (STEM) careers in the future, motivation and interest can be identified as the most important concepts of this research. Chapter 4 is devoted to the explication of these concepts and their relation to school science.

1.1 Research tasks

This study is an interaction between design and research; to explicate this interaction, the construction of design and research is considered in two stages.

In the first or design stage, a teaching sequence was designed in order to disrupt students’ stereotypical notions not only of science occupations in general but also of their own possibilities in the field, and to offer them a new perspective that is complementary with the one they adopt within ordinary science lessons, combining what they have learnt at school with life outside the school. As the students see the broader aspects of science compared with those they see in the classroom, their feelings of personal relevance of science studies may increase, and they may become more interested in studying science. The most significant aim was to generate a phenomenon to be inves-
tigated in the research stage. The design process and decisions related to it are described in the research report.

In the second or research stage, the aim was to clarify which specific aspects of the design appealed to particular students and enhanced their motivation and interest, and what scientific content students learnt within the project. While in the design stage the focus was on how students’ motivational orientations influenced the way they experienced the sequence, the research stage concentrated on what kind of effect the designed sequence had on those motivations. Both directions of the interaction between the designed sequence and students’ motivation were examined.

In this research project, a site visit teaching sequence was implemented in several cycles. The research problem has been divided into three separate substudies, each having a different approach to the project. The first substudy deals with the problematics of the design, the second with motivation in general and different motivation orientations, and the third one about the acquisition of scientific content in the sequence. The specific research questions of the three substudies are introduced in the following sections.

1.1.1 The first substudy

The research in the first substudy relates to literature that concerns the principles of design-based research. The emphasis was on the process of designing the teaching sequence and decisions that were made during the design process, especially the rationale behind each decision. The research question is:

How was the site visit teaching sequence designed and revised during an iterative process according to the theory-based conjectures about motivation and interest, and what did the analysis of these conjectures reveal?

1.1.2 The second substudy

The research in the second substudy builds on literature about students’ motivation and adopts the perspective of self-determination theory. Individual differences in the motivational profiles of the students were the focus of this substudy. The research question is:

How did students with individual differences in their motivation orientations experience a teaching sequence enriched with motivation and interest promoting features?
1.1.3 The third substudy

This study is situated in the context of science education, and therefore the potential of the teaching sequence for promoting students’ science learning is vital to examine. The third research question is related to literature about the contextual aspect of learning. The research questions of the third substudy are:

What was the difference between students’ outcomes before and after the site visit teaching sequence?

and

How did students with different motivation orientations describe their learning during the site visit sequence?

1.2 Structure of the thesis

The same data (for example, the questionnaire data and student interviews) have been used for multiple purposes in this study. Before the chapters concerning substudies, there is thus a chapter dealing with data collection. Data collection issues are also considered in the substudy chapters if there are some specific aspects that are relevant to that particular substudy. The substudies naturally have some overlap, such as the evaluations of the potential and success of the teaching sequence in motivating students (Chapter 9) and examining the potential of the teaching sequence from the point of view of students’ different motivation orientations (Chapter 10).

In the first substudy, the viewpoint of DBR has been adopted, and justifications for the decisions made within it are scrutinised. For the purposes of this substudy, interview data have been used to revise the teaching sequence so as to find means of improving the sequence to make it more suitable for the reality of schools and for the purposes of different teachers. In the second substudy, the motivating features of the designed teaching sequence are investigated in order to understand how students with different initial motivation orientations experienced the teaching sequence, in which industry site visits held a central place. The data have been used in order to generate a detailed understanding about the role of students’ different motivation orientations in the context of science learning. The third substudy examined what students learnt during the sequence. All three substudies are followed by discussions. At the end of the thesis, a general discussion revisits and consolidates the different perspectives on the topic.

Chapters 7 and 9 focus on the characteristic features of the designed teaching sequence. In Chapter 7, the structure and intended learning outcomes of the sequence are presented, whereas Chapter 9 is devoted to the
design process of the sequence and the explication and research of the embodied theory-based conjectures of the design.
2  Pragmatism as a paradigm for educational research

This chapter introduces the philosophical commitments of this research. As a methodological framework, a design-based research approach (DBRC, 2003) has been followed in planning and refining the teaching sequence that consists of site visits and related learning activities. DBR is a general framework for design, development, implementation, and evaluation of learning activities. Juuti and Lavonen (2006) have summarised the essential aspects of DBR as follows: firstly, the design process is essentially iterative, which addresses the validity of findings, and the alignment of theory, design, practice, and measurement (DBRC, 2003). Secondly, DBR produces new knowledge, i.e., novel theories of teaching and learning. Finally, DBR generates artefacts that assist teachers and students to act in a way that encourages learning. With the artefact, which is made up of conjectures about the relation of the instructional context and learning, a new phenomenon is generated and then this phenomenon is examined. During the design implementation, the conjectures are studied and specific aspects related to the context are uncovered (Sandoval, 2004). Other important characteristics of DBR are that it emphasises collaboration between researchers and practitioners, and that it takes place in a real-world setting (Wang & Hannafin, 2005); rather than aiming for impressive results produced under ideal conditions, it focuses on outcomes that are produced under often-difficult realistic constraints, in order to generate something genuinely applicable (Walker, 2006).

There is a wide range of authors in the field of combining design and educational research, and these authors approach the topic from different backgrounds. For example, the editors of the book Educational Design Research (2006) build strongly on the socio-constructivist tradition (Gravemeijer & Cobb, 2006). However, besides the goal of improving science teaching and learning with the designed artefact, Juuti and Lavonen (2013) emphasise the utility of the artefact and requirements of disseminating the innovation and convincing sometimes-reticent teachers to adopt it. To facilitate the adoption process, it is essential to respond to problems in real practice that have been identified by teachers and students. This condition of generating applicable results anchors design-based research naturally in the philosophical ground of pragmatism. In their articles (2006, 2013), Juuti and Lavonen have explicated the relation between the DBR and pragmatism, and argued how and why pragmatism may be interpreted as a philosophical background for DBR. Furthermore, because educational research is inherently concerned
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with learning, the contemporary view of learning must be taken into consideration and acknowledged to have a central role in any design.

Critical pragmatists (Kivinen & Ristelä, 2003a), however, argue that pragmatist philosophy and a constructivist view of learning do not fit together in every respect. In this chapter, I try to determine how to interpret these two approaches to avoid having conflict between these two philosophical orientations derail the study’s focus on optimal learning conditions.

2.1 Basic ideas of pragmatism

Pragmatism can be defined as a philosophical orientation that emerged from the writings of Charles Peirce (1839–1914), William James (1842–1910), and John Dewey (1859–1952) (Pihlström, 2008); it has been widely described as the first truly American philosophical movement. There is of course not merely one pragmatism, but many, covering a wide range of philosophical topics (Pihlström, 2008). The most important pragmatist from the educational research point of view is John Dewey, a significant educator and philosopher who wrote extensively about the process of scientific inquiry. Many of Dewey’s ideas remain deeply relevant today in the context of educational research (Biesta & Burbules, 2003).

According to Biesta and Burbules (2003), pragmatism is as pertinent today as it was more than a century ago, when the pragmatists began to criticise the disconnected and dehumanized way in which Western culture had for more than two thousand years conceived of knowledge and reality. Pragmatists argued that philosophy should take the insights and methods of modern science into account, and should reject the ontological and methodological distinction between scientific and social approach to science (Pihlström, 2008). An example of this is using the experimental method in the process of acquiring knowledge, which implies a close connection between knowledge and action. Dewey does not prioritise the empirical method over other methods, but argues that all scientific methods sprout from the same logic (Kilpinen, 2008).

As Biesta and Burbules emphasise, Dewey’s view of the status of action in the knowledge acquisition process is radically different from the mainstream tradition of Western philosophy. They remind us that Western philosophy dates back to an ancient Greek view that knowing was much more valuable than doing; the practical had a lower status compared to theoretical. From the Greek philosophers’ point of view, it was theory that had to find out how and what reality was, and thus action was cut off from the process of acquiring knowledge. Actual reality could not, for these thinkers, have been the reality of practical life but had to be the static reality of the life of theory.
Problems began to arise when the mechanical worldview of modern science started to emerge in the wake of Copernicus, Galileo, and Newton among others, and the ideal of immutable stability was no longer supported by all viewpoints.

Although the founders of pragmatism were influenced by European philosophy, pragmatism differs from that tradition in one vital respect: pragmatists argue that philosophy should take the experimental methods and insights of modern science into account. In so doing, Dewey and his peers argued that the division between knowing and acting can disappear completely. Dewey argued that the results of modern science should not be interpreted in the framework of Western philosophy, in which the point of departure is the human consciousness and its separation from the material world, but that the starting point should be action, or more precisely the transaction between an organism and its environment. One difficulty of understanding Dewey’s approach is that he uses many of the concepts and terms of the philosophical tradition in a new and different way. The main difference between Dewey’s work and traditional Western philosophers is how Dewey takes the concept action as its most basic category (Biesta & Burbules, 2003).

2.2 Pragmatism and educational research

Beliefs about knowledge and how it is acquired and constructed (i.e., epistemology), about reality, especially the question of whether there is one objective reality or whether each person has a unique subjective reality (i.e., ontology), and beliefs about human action and its position in the process of acquiring knowledge, are central to the relationship between educational research and educational practice. Juuti and Lavonen (2013) note that according to Dewey’s view of knowledge as an organism-environment interaction, knowledge can be seen as a construction that is located in the interactions among the teacher, the researcher, and the learning environment (classroom settings, social and psychological environments, students’ motivation, their interest in and preconceptions of a topic, their goals, etc.). The way that Dewey has connected knowledge and action is especially relevant for educators and educational researchers, those for whom knowledge should always be approached from a practical perspective (Biesta & Burbules, 2003).

A crucial point in Dewey’s theory of action is that he assumes that it is possible to transform simple action into planned, intelligent action which has a purpose for research, including educational research. Action can be turned into intelligent action through the key process of reflection. Thinking is a way to experiment with different ways of acting without having to perform the action in the real world. This is an enormous advantage over the trial-and-
error method, especially if some results of an action might be unwanted. Thinking lies in and depends on the use of symbols, e.g. language. In Dewey’s opinion, the ‘discovery’ of symbols and symbolization is the single greatest event in the history of man (Biesta & Burbules, 2003).

Since the beginning of systematic inquiry into education, educationists have emphasised the necessity of a practical orientation for educational research (Biesta & Burbules, 2003; also DBRC, 2003). As they interpret Dewey, educational practice is the central point, the beginning, and the end—the alpha and the omega—of all educational inquiry. It is of course the source of the problems to be solved, but also serves as the final test of the value of any provisional solutions. The educational practitioner is the central figure in the study of education. Dewey stressed the one and only purpose of educational inquiry is to make the actions of the educator more intelligent, arguing that the actual science of education exists in the use of the outcomes of an educational inquiry in a real-world educational situation. A further implication of this view is that for Dewey teachers should themselves be at least partly investigators. It is only when teachers approach their own educational practices with an inquiring and reflective attitude that intelligent educational action becomes possible. Dewey argues that educational research should not simply be research on education and educators, but should involve educators themselves in a meaningful way.

As Biesta & Burbules (2003) encapsulate it, Dewey’s description of the process of inquiry is very close to our everyday understanding of how to deal with problems. First, we identify what the problem is, then develop a strategy for dealing with it, and finally we test the strategy. If successful, we have a solution for our problem may even claim further that the solution means that we correctly understood the problem. This simple procedure can be transferred into a more abstract, ‘philosophical’ level, at which the phases of the procedure becoming drawing up a hypothesis, developing an experimental strategy, performing experiments, observing results, and finally concluding on the basis of evidence gained through experiments. From the Dewey theory’s point of view, this cycle of empirical research should be understood in terms of the transactional theory of knowledge acquisition. The result of the process is not the an objective, otherworldly truth but an honest description of the relationship between our actions and their consequences.

### 2.3 Learning and pragmatism

The modern approaches to learning that can be applied in school environments (e.g., Bransford, Brown, & Cocking, 2000) conceptualise learning as an active process, with the emphasis on understanding and problem-solving
skills. Through the process of active thinking and understanding, simple information evolves into knowledge. Learners construct new knowledge and understanding based on what they already know and believe, and organise it in ways that facilitate retrieval and application. Learning with understanding prepares students to transfer what they have previously learnt to new problems and settings.

An important feature of learning is appropriate feedback from the teacher, and the process of reflecting one’s own learning process helps the learner get familiar with her own learning strategies and modes of thinking. These reflecting skills are developed in the interaction with both teacher and peers, and they help students learn to take control of their own education by defining learning goals and monitoring their progress. All the above aspects relate centrally to the constructivist tradition.

As Phillips (1995) has noted, there is a vast number of constructivist writers, and the more one widens the scope, the more authors can be considered constructivist. Phillips attempts to categorise those who refer to themselves as constructivists and their views about learning and acquiring knowledge. His article “The Good, the Bad, and the Ugly: The Many Faces of Constructivism” (1995) classifies constructivist authors by using three different perspectives. The first is whether emphasis should lie in the knowledge construction process of an individual or on the construction of human knowledge in general. The second perspective concerns the kind of thinking that can be regarded as constructivist; authors with minimal constructivist orientations consider knowledge as something discovered by a basically passive individual—active effort is less significant—whereas those with stronger constructivist orientations see the human being as an active creator and constructor of her knowledge structure. The third of Phillips’s perspectives deals with the definition of activity: Is activity described in terms of individual cognition or in terms of social activity? Is activity physical or mental? An important character in the field of active constructivism is Dewey, whose writings also constitute the foundation for many pragmatic orientations. As Phillips recapitulates, Dewey stressed the active participation of the individual instead of adopting the view of a spectator that is cognitively, but not physically, active. A consequence of being physically active and participating in the action is that the individual has the opportunity to influence on the environment (1995).

Kivinen & Ristelä (2003a), however, discuss interpret Dewey’s work and some constructivist writings, and they argue that the interpretation of the concept of activity is the major feature that distinguishes the pragmatic view of learning from the constructivist one. They claim that in constructivism activity is be interpreted as being thoroughly conscious of the processes of
learning and one’s own thinking when constructing new knowledge. From the pragmatist point of view, learning is also an active process, but in a bit different sense. As Kivinen and Ristelä (2003a) interpret Dewey, people are active because they cannot exist without acting, and no specific attention is required to be active; to be is to act. From their Deweyan perspective, people learn most of the important skills they need in their lives, such as walking, without explicitly concentrating and paying attention to the learning process; they focus on the activity instead. This does not mean, however, that reflecting on the activity and experiences was unnecessary.

From a Deweyan pragmatist point of view, experience is the way in which organisms connect with reality. Experience per se does not produce knowledge; action and reflection or thinking are also necessary. Reflection can be conducted within the action itself, known as reflection-in-action, or retrospectively. The more capable the actor is, the more reflection takes place within the action (Kilpinen, 2008). According to Biesta and Burbules (2003), Dewey claims that the combination of reflection and action leads to knowledge. Knowledge is connected with the relationship between actions and their consequences and is in fact an action, ‘a mode of doing’. Knowledge offers the possibility to control actions, a step removed from the trial-and-error method, especially when one does not know with certainty the best possible way to act.

An important concept in constructivism, serving as something of a corresponding term to reflection in pragmatism, is the concept of metacognition, which refers to knowledge about how an individual can control her own learning, what one considers effective learning strategies, and when one thinks it is best to apply these strategies (Gunstone, 1994). Do we know what we have been thinking because we have been thinking, or have we actively been observing our thinking in a process that is somehow separate from that thinking itself? It appears that pragmatism takes a simpler approach to this issue, but no matter what the process is called, it is important from an educational point of view that the learner is conscious of her own actions and intentions.

Criticism expressed by Kivinen and Ristelä (2003a) is approached from three perspectives that are common to pragmatism and constructivism. The first aspect is the view of truth. Both Dewey for the pragmatists and Jean Piaget, a founder of constructivism, have an anti-representational view of truth, meaning that neither considers knowledge a representation of an independent reality. Dewey’s alternative to this objectivist and representational view of truth is not, however, relativism, but intersubjectivity: the only reality that matters is our common and shared reality, and we share common responsibility for our common world (Biesta & Burbules, 2003).
The second aspect common to these two philosophical approaches is the way activity is emphasised, in contrast to, for example, behaviourist views of learning. As we saw in the previous chapter’s discussion of activity and its definition in constructivism, Dewey’s views on activity, on participating in the action and thus being in interaction with the environment, formulate the basis for both pragmatist view of learning and for certain forms of constructivism. Dewey’s theory of the organism-environment transaction (known as functionalism) was a critique of the contemporary dualistic stimulus-response theory (Biesta & Burbules, 2003). Dewey characterised the transaction as a process of continuous readjustment, not simply as an external stimulus followed by an organism’s response. The organism doesn’t need a stimulus to be set passively into action, because the organism is already active and maintains a dynamic relationship with its ever-changing environment. This organismic view shares aspects with the self-determination theory of motivation (SDT), as it emphasises an innate tendency toward integration of the self and fulfilling one’s potential, but also takes social-contextual factors into account (Ryan & Deci, 2002). Through this process of a dynamic transaction, the predispositions of the organism become more specific, and the organism has thus learned; the world becomes more differentiated and meaningful for the organism. This view is also fostered in the field of educational science, where Miettinen (2008) argues that physical interaction with the environment is a basis for knowing and that knowledge can be said to be located at the interaction. For example, in the context of schools and education, knowledge about teaching science is inherent in the actions of the science teacher (Juuti & Lavonen, 2006, 2013).

According to Biesta & Burbules (2003), the third aspect common to pragmatism and constructivism is that the separation between theory as a domain where knowledge is acquired and practice as a domain where knowledge is applied cannot be sustained. From the Deweyan point of view, theory is not only about knowledge and practice not only about action, but both contain a mix of knowledge and action, and the difference is which one of these may be emphasised. Dewey gave priority to the practical, and rejected the idea that knowledge produced by science should automatically possess cognitive superiority to everyday knowledge. For Dewey, it is not that theory tells us how things are and practice’s role is to follow theory’s orders, but that theory emerges from and feeds back into practice. This view is compatible with processes of DBR, as theory and practice are intertwined throughout the process and feed back to each other (Edelson, 2002, 2006). Science, including educational science, is as much a practice as everyday practice is. It is a more human and down-to-earth enterprise than some traditional interpretations allow us to recognize.
As the constructivist views about learning that date back to Dewey’s writings are taken into account, it is clear at a minimum that student activity should be emphasised at the expense of a passive spectator role for students. Modern views of inquiry-based learning, for example, can provide novel alternatives for school arrangements. From the DBR point of view, regardless of the background of the authors, there is a consensus agreeing on the value of many features that are inherent in DBR, no matter what name it is given.
3 Design-based research approach

In this chapter, the methodological background of the research, namely the design-based research approach is explained. DBR means a systematic study of designed interventions (Sandoval, 2004), and can trace its origin to Ann L. Brown’s 1992 article “Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings” (Edelson, 2002; Juuti & Lavonen, 2006). Ideas similar to Brown’s, especially the notion of applying aspects of developmental research in educational settings, had also emerged in the Netherlands as early as the Seventies. However, it was not until the Nineties that fuller development of these concepts occurred, at about the same time as Brown’s seminal article was published (Gravemeijer & Cobb, 2006). Over the history of this research approach, it has been called by a variety of names: ‘design experiments’, used by Brown (1992); ‘educational design research’, used for example in the books Educational Design Research, edited by van den Akker, Gravemeijer, McKenney, and Nieveen (2006) and An Introduction to Educational Design Research (2007), edited by Plomp and Nieveen; and ‘design-based research’, suggested by the Design-Based Research Collective in 2003 and used by variety of authors (Barab & Squire, 2004; diSessa & Cobb, 2004; Wang & Hannafin, 2005).

Beyond terminology, these approaches also differ from the point of view of their philosophical underpinnings. The Dutch group, which uses the label design research, has a strong background in socio-constructivism. Juuti & Lavonen (2006), meanwhile, suggested that the relatively new research approach should be anchored in pragmatism, especially in the light of Biesta & Burbules’s interpretation of John Dewey’s writings. The pragmatist and socio-constructivist views and how the philosophical background of DBR is understood in this research were discussed in the previous chapter. Despite the philosophical disagreements of different authors, there is a consensus about many characteristics of DBR, and scholars’ views may be combined in a way that is both valuable and consistent.

The following chapters elucidate the essential features of DBR, the distinction between DBR and traditional methodologies of educational research, the charges of implausibility that DBR has faced and, finally, suggest some strategies for increasing the methodological rigor and thus trustworthiness of DBR.
3.1 Why is DBR a relevant methodology for educational research?

Educational research has been criticized for not having generated any recent, significant results that have had a real impact on educational practice, from the point of view of the most common problems in schools (motivational problems and poor learning results). By comparison, in many other disciplines (e.g., medicine, engineering, basic science, etc.), there has been major progress in recent years (Walker, 2006). Walker argues that the problem of educational research is that it does not influence practice sufficiently; in other words, research-based teaching methods show no significant effects compared to traditional methods that are not based on new research (Walker, 2006). Thus, a research approach is needed that speaks clearly in the language of practical problems that teachers face, but that is still plausible to the world outside the educational research community and employs scientific methods. According to Edelson (2002), the varied and serious problems faced by our educational system call for true innovation.

Because context plays a central role in the implementation of the results of educational research, it also should be taken into account in the research phase. Accordingly, examining aspects of learning and education as isolated variables in artificial laboratory settings lead, first of all, to an incomplete or even false understanding of both teaching and learning and, secondly, to results that are unlikely to have any practical impact on real educational problems. On the other hand, because real educational settings may be too complicated to be understood and explained by simple observation, something between these two extremes offers the most fruitful method for investigating the phenomena that take place in the school context. Therefore, we need limited and explicitly-defined interventions that take place in authentic contexts and attend to social interactions that indisputably influence holistic results (Barab & Squire, 2004).

DBR is an emerging method in the field of educational research, and the number of educational researchers who situate their studies into practical contexts is growing rapidly (van den Akker, Gravemeijer, McKenney, Nieveen, 2006). Because DBR is grounded in the needs, constraints, and interactions of local practices, it has the potential to produce the kind of impact on practice that research has made in other disciplines (DBRC, 2003; Walker, 2006). DBR eliminates the boundaries between design and research and between research and practice. Thus, it advances a researcher’s understanding of the complexities of educational contexts—the interactions between many variables at multiple levels (Cobb, Confrey, di Sessa, Lehrer & Scauble, 2003)—and, hence, of teaching and learning themselves (Edelson, 2002).
With DBR, practitioners and researchers work together in order to produce meaningful change in the situated context of practice. Such relationships help maintain the balance between tailoring intervention that can function in an actual setting and keeping in mind the demand of generalizability to other settings that is essential from the point of view of plausibility of the research approach (DBRC, 2003).

What distinguishes DBR from methodologies that encompass apparently similar aims, such as action research or more general applied research or development work (Cohen and Manion, 1994)? Applied research can be understood as further development of the results of basic research, but also applying research results to a problem that is set from outside the scientific community. However, the term applied research is relatively vague because research can be at in many ways for many purposes (Niiniluoto, 1999). Developmental work, in turn, aims at more concrete objectives, some of which can be highly commercial. DBR has commonalities with both of these perspectives, as a form of applied research aiming at generalizability and having potential for product development, but it is distinctive because of its methodology of inseparable features and phases, as described below.

Another research approach mentioned above, which involves researchers and practitioners working together towards improvements is action research (Cohen, Manion, & Morrison, 2007). Cohen and Manion (1994, p. 186) define it as follows: “Action research is a small-scale intervention in the functioning of the real world and a close examination of the effects of such intervention”. It is context-specific, participatory, and collaborative. The major distinction between DBR and action research, which focuses on improvements within a certain context, is the generalizability of the results. The findings of action research are generalizable only into the future within similar contexts. In the best cases, some of its results can be adapted to different settings, but significant modifications need to be made. DBR, by contrast, aims to design solutions that are not dependent on context. The generalizability requirement of the results of a DBR project is discussed further below.

DBR combines empirical educational research and theory-driven design of learning environments. It is not a deduction from theory, or merely testing a theory in practice via a traditional development-implementation-assessment-refinement cycle. Instead, it is a method of transforming theoretical claims about teaching and learning into effective educational settings (DBRC, 2003) and of developing and refining new theories. As it takes place in complex, real-life settings, the design process reveals inconsistencies more effectively than analytic processes that arise from outside the setting, and the results of the design process are directly applicable to educational practice (Edelson, 2002).
In order to justify the principles of DBR and to increase the trustworthiness of this mode of research, the manner of reconciling theory-based learning principles and a practical educational innovation has to be rigorous. Innovations embody specific theoretical claims about teaching and learning (DBRC, 2003). It is imperative that teachers and parents be offered educational innovations based on the most promising theoretical understanding, but it is also important to grasp how, when, and why educational innovations work in practice (DBRC, 2003). If new educational innovations in schools are not rooted in firm theoretical bases, education will be dominated by innovations that merely follow fashion and marketing considerations (Walker, 2006).

3.2 Characteristic features of DBR

Sandoval (2013) argues that the characteristic feature of DBR is that this approach is simultaneously concerned about three commitments that education research in general treats separately, namely the production of innovative learning environments, the generation of knowledge about how such environments work in the settings for which they are designed, and the generation of more fundamental and translatable knowledge about learning or teaching. There is a dual commitment to improving educational practices and furthering our understanding of the processes of learning and teaching.

The design process is grounded in theory (Edelson, 2002, 2006), and the designing takes place as a shared activity of researchers and teachers in order to generate solutions that facilitate more effective ways of teaching and studying (Juuti & Lavonen, in preparation). Being grounded in theory means that the theory-based conjectures, which are embodied in the design, are specified and laid out in advance (Sandoval, 2013). Such explication enables testable predictions, the results of which may lead to both refinements of a particular design and to revisions of the broader theoretical perspective (Sandoval, 2004, 2013).

The iterative design process is carefully documented and formally evaluated throughout the whole project (DBRC, 2003; Edelson, 2006), and leads to a generalizable educational innovation and novel knowledge about aspects of teaching or learning (Edelson, 2002, 2006; Juuti & Lavonen, 2013). The iterative nature of the process is essential, because the iterations address the validity of findings, alignment of theory, design, practice, and measurement (DBRC, 2003). In addition to the demand of a background theory, DBR must also take seriously considerations of teachers’ needs and school practices (Juuti & Lavonen, 2013), as it generates artefacts that help teachers and students to act in a way that leads to learning. The artefact is also widely usable...
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in settings other than the original one. The characteristics essential to a certain design solution for achieving specific goals in a particular context need to be explicitly articulated (Edelson, 2002). In fact, the aims of designing the artefact and developing new theories of learning cannot be separated; they are inter-dependent (DBRC, 2003).

Other important characteristics of DBR are that it is interventionist, involving some sort of design (Cobb, Confrey, di Sessa, Lehrer & Scauble, 2003; Edelson, 2006; Walker, 2006), and it takes place in a real-world setting (Wang & Hannafin, 2005). Robust designs are needed, not those that produce impressive results only under ideal conditions but those that produce results under thoroughly realistic constraints that generate something genuinely practicable and pragmatic (Walker, 2006). Collaboration of participants must be maintained throughout the research, even though the several cycles of a study may take years (DBRC, 2003).

The iterative design process starts when something is considered problematic in a specific educational context. Conducting theoretical problem analysis by exploring the relevant research literature of the pedagogical field guides the choice of the best way to approach the problem (Juuti & Lavonen, 2006). Problem analysis defines the context, challenges, the desired outcomes, and the ways of achieving them, and it is often constructed together with the design solution; they develop hand-in-hand (Edelson, 2002). Development and research take place through iterative cycles of design, enactment, analysis, and redesign (DBRC, 2003). The successive iterations of test and revision have a role similar to systematic variations in experiments (Cobb, Confrey, di Sessa, Lehrer, & Scauble, 2003).

Edelson (2002) has categorised different types of theories that can be generated during a design process. The concept of ‘design framework’ involves a prescriptive generalization of a design solution and a collection of coherent design guidelines of a given DBR project. The design framework has to be defined according to the essential characteristics an artefact must have in order to achieve its particular goals in a particular context. Another type of theory he discusses is ‘design methodology’, which is a generalization of a design procedure of a certain DBR project. Design methodology is prescriptive and it defines the process, the expertise required, and the roles of the various participants in DBR projects. Finally, according to Edelson, DBR generates ‘domain theories’ that describe important phenomena in the field of education rather than within the design process. Other authors in the DBR field (e.g., diSessa & Cobb, 2004) have slightly different theoretical categories than Edelson, but instead of concentrating on such distinctions, it is more useful to emphasise the fact that an essential feature of DBR is that it generates new educational knowledge.
There is no single, immutable DBR method. The explicit concern of DBR is the use of methods that link the design process with the desired outcomes. This connection generates knowledge that is applicable to educational practice (DBRC, 2003). In DBR, particularised task design determines the nature of data collection and analysis (Juuti & Lavonen, 2006). DBR methods respond to emergent features of the setting; furthermore, issues that arise out of the research setting also inform the design process. Triangulation from multiple data sources, mixed methods in data collection, repetition of analysis during cycles, and use of standardised measures or instruments can all help promote reliability. Processes should be documented in order to provide critical evidence about why certain outcomes occurred (DBRC, 2003). In this sense, data collection methods similar to those recommended for case studies (Yin, 1994) can also be used in DBR. With respect to data collection, the challenge that arises is that large amounts of data result from the combination of ethnographic and quantitative analysis (Joseph, Collins & Bielaczyc, 2004).

3.3 How to increase the plausibility and trustworthiness of DBR?

As already discussed in previous chapters, most people in the field of education generally and educational research in particular agree that a research approach that takes into account the complex and interactive nature of the real educational settings, that aims to go beyond narrow measures of learning and that takes the existing theories into account, is infinitely preferable to those approaches that split as complex a phenomenon as learning into isolated factors that are examined separately in sterile laboratory settings. However, because the broader research community is used to evaluating research according to the traditional criteria of objectivity, reliability, and validity, it can be difficult to convince other researchers of the usefulness and plausibility of DBR as a new and still-evolving methodology for promoting ever-new and improved practices (diSessa & Cobb, 2004). As Collins, Joseph, and Bielaczyc (2004) suggest, in order to become a widely-accepted research approach, the learning-sciences community must create standards that make DBR recognizable, accessible, and acceptable to other researchers.

The first and most significant aspect concerning the quality of any given DBR project is the criterion that is important in all research, regardless of methodology or field: the research needs to be relevant and must yield insight concerning an important problem or need (Edelson, 2006). Questions about the quality of DBR can be approached from two perspectives, either the re-
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To agree that DBR is a plausible research approach, the audience must be convinced specifically about what distinguishes and delineates it from other forms of research. Collins, Joseph, and Bielaczyc (2004) and Barab and Squire (2004) specify some aspects in their summary of Collins’ (1999) earlier conclusions about the distinctive features of DBR compared to other research modes. In contrast to traditional laboratory experiments that aim to control variables and test hypotheses and that isolate the learner in order to control social interaction as a ‘variable’, DBR focuses on understanding the complexity of real educational settings, with the rich, socially-situated context being an essential aspect of the study.

Design research should be evaluated in terms of the novelty and usefulness of its results, not merely by the traditional criteria of applied research; the process should yield theories that are useful in solving significant problems. The outcome of the design process should, in other words, be relevant from the point of view of improving the practice. Those involved in using the design solutions can also participate in evaluating it (Walker, 2006). The theories that are generated through design research approach are impossible to generate in any other way, such as the use of traditional empirical methods (Edelson, 2002). The usefulness of the research results is evaluated based on their practicality for real users (van den Akker, Gravemeijer, McKenney, Nieveen, 2006; DBRC, 2003); furthermore, because DBR focuses on linking the process with the results (DBRC, 2003), not only the results but also the entire design-research process is validated through consequences arising from the project’s findings and innovations (Barab & Squire, 2004). A research design is valid to the extent that it successfully takes into account the issues that are raised during the design process (Edelson, 2002).

Another challenge for DBR lies in finding a balance between refining a particular innovation in order to maximise its success, and generalizing findings from such a highly-refined situation to a different set of conditions (DBRC, 2003). The context-bound nature of much design research explains why it usually does not strive toward completely context-free generalizations. However, designer-researchers need to strive for optimizing the design in the local context without decreasing its generalizability (Wang & Hannafin, 2005). Through collaboration and iteration, this aim is realistic. It is important to determine the factors that have resulted in desired outcomes. Even apparent failures also contribute to the resulting theory (Edelson, 2002), because failure of a design is not a failure of the research, but an opportunity to determine what needs further improvement.
4 Motivation and interest in science education

Motivation, in general, refers to the process of generation and maintenance of goal-directed activities (Schunk, Pintrich, & Meece, 2008). In the literature, motivation has been considered from various viewpoints. One approach to conceptualising motivation is to view the phenomenon from the perspective of an individual actualising her innate tendencies for integration and development. Self-determination theory (SDT) is an example of this paradigm (Deci & Ryan, 1985, 2008; Ryan & Deci, 2002). This thesis approaches motivation from the perspective of SDT, which will be explicated more fully in the following sections. Another approach to motivation is the socio-cognitive view, which emphasises cognitive structures such as beliefs, decision making, appraisals, and conscious goal-setting of an individual that take place in the presence of certain social-contextual factors. The expectancy-value theory of motivation is an example of this paradigm. According to this theory, motivation towards a certain task depends on the one hand on an individual’s expectations for success and self-related beliefs, and on the other hand on values associated with the particular task (Pintrich, 2003). These task-related values can be categorised as attainment value (importance or significance), intrinsic value (enjoyment), utility value (instrumental benefit), and the costs of engaging in the task (Viljaranta, Nurmi, Aunola, & Salmela-Aro, 2009). In particular, considerations of attainment value, utility value, and task costs are a result of conscious cognitive activities in a certain social context. Motivation can also be considered from the perspective of environmental consequences, such as offering rewards that enhance the probability of desirable outcomes (e.g. Schunk, Pintrich, & Meece, 2007). Even though many tasks at schools may be presented to students in a way that the value of the task is emphasised to students, they still may appear rather alien to students if the values are not personally adopted and embraced by them.

4.1 Individual differences in motivation orientations and the role of basic psychological needs

The leading idea of SDT is that humans are active and growth-oriented, seeking the actualisation of their potential, growth and integration, fulfilling their needs for autonomy, competence and social relatedness, and moving their lives in desired and specific directions, rather than being passive subjects that environmental forces push around. As humans do not live in a vacuum, their social environments can either facilitate or inhibit these inherent tendencies
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(Ryan & Deci, 2002). The three basic psychological needs are the need for competence (the desire to feel efficacious, to have an effect on one’s environment, and to attain valued outcomes), the need for autonomy (the desire to be self-initiating and to have a sense of acting in accordance with one’s own sense of self), and the need for relatedness (the desire to feel connected with and to be accepted by significant others) (Ryan & Deci, 2002).

These basic needs, which are assumed to be innate for all humans in spite of cultural differences and across all situations, do not affect behaviour in a vacuum, but their effects are mediated by social-cognitive constructs that are more context-specific, such as the regulatory style or motivation orientation of a person (Ryan & Deci, 2000). From this perspective, motivation can be seen as a result of interactions between an individual’s need system and the environmental factors that interfere with or support the need fulfilment process. More specifically, the theory is interested in individual differences resulting from “the degree to which the needs have been satisfied versus thwarted” (Deci & Ryan, 2008, p. 183). Students come from different backgrounds and have different prior experiences related to learning situations. These prior experiences, in turn, have influenced any particular student’s motivational profile. In other words, a person’s motivation in a particular situation is a function of the immediate social context and of the person’s inner resources that, in turn, have been affected by the prior interactions with social contexts (Ryan & Deci, 2002; Vansteenkiste, Williams, & Resnicow, 2012). The continual interface with the social environment can either support and facilitate the natural growth process or block it by frustrating basic psychological needs (Vansteenkiste, Williams, & Resnicow, 2012). In one of the variants of SDT, cognitive evaluation theory (CET), Ryan & Deci (2002) suggest that there are two cognitive processes through which contextual factors affect motivation, namely changes in ‘perceived locus of causality’ and ‘perceived competence’. The former refers to the degree to which a person has a feeling of control over a particular activity and the latter to the degree of mastery of and competence in the activity. The more external the locus of causality is perceived, the less a person’s need for autonomy is supported. Keeping in mind the wide variety of students’ previous experiences concerning the fulfilment of basic psychological needs and the variety of environments from which students come, it is easy to grasp that the science class environment is not experienced identically or even similarly by all the students; they do not have comparable prior expectations and emotions towards an activity or topic.

In the research literature, students and their motivational profiles have been categorised in various ways, from the perspectives of different paradigms within motivational science. Viljaranta et al. (2009), for example, categorise students in relation to how they see the value of different school
subjects. They ground their categorisation on the arguments of the expectancy-value theory that is a cognitively-oriented motivational theory. Related to the lifespan model of motivation, which assumes that basic psychological needs constitute motivational processes, Salmela-Aro (2010) presents a categorisation of motivation orientations in which adolescents’ personal goals and how they reflect their basic psychological needs play the central role. SDT proposes a distinction between motivation orientations that is based on the regulatory style of a certain person and is related to the quality of motivation (Ryan & Deci, 2002). One of the sub-theories of SDT, organismic integration theory (OIT), concerns internalisation of the regulation of behaviour and values and, furthermore, the influence of the fulfilment of basic psychological needs on regulatory style and motivation orientation. Regulation of behaviour may be autonomous (self-determined) or controlled, depending on the degree of internalisation. Internalisation is not viewed in terms of a simple dichotomy of external versus internal, but rather as a continuum (Ryan & Deci, 2002). OIT proposes a taxonomy of regulation types ranging from non-regulation to intrinsic regulation. Non-regulation, at one end of the continuum, is related to amotivation. Controlled and ill-internalised regulations, namely ‘external’ and ‘introjected’ regulations are related to controlled forms of extrinsic motivation, while more autonomous forms of extrinsic motivation encompass ‘identified’ and ‘integrated’ regulations. The other end of the continuum, ‘intrinsic’ motivation, is a prototype of autonomous and self-determined behaviour. Along the continuum, internalisation of the regulation of behaviours increases and the motivation for certain behaviours becomes more autonomous (Ryan & Deci, 2002).
‘Amotivation’ is a state of lacking any intention to act (Ryan & Deci, 2002), and amotivated students cannot find any reason to engage in a certain activity. Amotivation may result from a lack of perceived competence or deficiencies in valuing the possible outcomes of an activity, and it is the most problematic motivation orientation in educational context.

‘Externally regulated’ behaviours are performed to earn some expected reward, or to avoid a threatened punishment; the underlying values of the activity are not internalised. In other words, externally-regulated behaviours are conducted to satisfy an external demand or socially constructed contingency (Ryan & Deci, 2002). ‘Introjected regulation’ refers to activities that are motivated by internal prods and pressures that are connected to the person’s self-esteem. Introjection-based behaviours are performed to avoid negative emotions like guilt and shame, or to attain ego enhancement and feelings of worth. Students with controlled forms of extrinsic motivation experience regulation of their activities external to themselves. They may not be inherently interested in a certain activity, but they engage in it because they value the activity as being important (Deci, 1992). Thus, people are unlikely to engage in extrinsically-motivated behaviours if they are not instrumental for some desired outcome such as a reward or the appreciation of significant others who value the activity (Ryan & Deci, 2002).

‘Identified regulation’ takes place when the regulation has become a part of the self; a person consciously feels the activity personally important or
valuable and participates in it willingly (Deci & Ryan, 2000). Even though the identification of regulation in relation to a certain activity may be separated from one’s other beliefs and values, identified regulation is relatively autonomous compared to external and introjected regulations. Finally, the most self-determined form of extrinsically motivated behaviour is ‘integrated regulation’, within which the activity has personal importance for a valued outcome. It occurs when identifications have been evaluated and brought into congruence with personally-endorsed values that already are a part of the self. Integrated extrinsic motivation shares many qualities with intrinsic motivation, but the difference is that intrinsically-motivated behaviours are done for the sake of interest and enjoyment, whereas behaviours controlled with integrated regulations are conducted to attain some personally-important outcomes. However, the behaviour can still be classified as autonomous, as the value of the outcome is well integrated with the self.

‘Intrinsic motivation’ is characterised by intrinsic regulation and self-determined behaviour. Intrinsically-motivated individuals engage in certain activities freely, directed by feelings of interest and enjoyment. According to Ryan and Deci “the basis of intrinsic motivation is interest” (2009, p. 177) and intrinsically motivated behaviours are conducted because of the inherent satisfaction of the behaviour per se, not because of any external consequences or reinforcements separable from the activity (Ryan & Deci, 2002).

It is important for a teacher to understand that there are qualitative differences in student motivation. Students with autonomous motivational profiles (intrinsic motivation and the well-internalised forms of extrinsic motivation) have higher grades, are more diligent in their studies, learn better, are more satisfied, and experience more positive emotions towards school in general (Guay, Ratelle, & Chanal, 2008; Niemiec & Ryan, 2009; Reeve & Halusic, 2009). In a broader context, autonomously-chosen goals are related to individuals’ increased likelihood of attaining their goals and thus enhancing their well-being (Vasalampi, Salmela-Aro, & Nurmi, 2009). Tuominen-Soini (2012) argues that students with mastery orientation and success orientation are both highly engaged in schoolwork, but as the success orientation is related to external aspects, such as competition with peers, these two orientations bear different relations to overall well-being, even though they may appear similar to the teacher. Desire to understand and enjoying learning per se are related to greater well-being (Tuominen-Soini, 2012).

The regulatory style of a particular student is important because it mediates the effect of a given psychological need on behaviour. Individual factors, such as cognitive and self-regulatory resources, influence how students cope with different levels of choice (Pintrich, 2003). The balance between choice and control has to be carefully considered to reach the best possible outcomes.
The classroom challenge is to organise an optimal amount of choice and control for all students, tailored to their different self-regulatory profiles. Individuals with different motivation orientations develop interest in science learning through engaging in activities that may fulfil their basic psychological needs, but different aspects of the activity appeal differently to students. For instance, students with autonomous motivation will refer to facts that might be related to their life goals, creativity, and personal development as important for their interest development, whereas students with extrinsic orientations will refer to facts that fulfil their needs for wealth, approval, and attractiveness as important for their interest development (Deci & Ryan, 2008). From the educational point of view, in an ideal situation students should identify with the importance of the curricular aims and thus fully accept them as their own. If intrinsic motivation is not evident, which might well be the case in a school context as the curriculum defines what the students have to study, it is still worth considering whether the learning task is introduced in a way that supports or controls autonomy. Internalisation of extrinsic regulation is essential for students to maintain appropriate orientation towards an activity if the activity is not intrinsically interesting (Niemiec & Ryan, 2009). Lavigne, Vallerand, and Miquelon (2007) argue that science teachers' support of student autonomy may have an impact on students' autonomous motivations towards science, and even on their pursuit of working in science-related fields. The time spent at school constitutes a great proportion adolescents’ waking hours, and therefore it is important that teachers internalise the significance of offering students autonomy, choice, and possibilities to enhance their feelings of competence and social relatedness. This study examines one possibility to realise these ideas in the context of science education.

4.2 Interest development

Interest motivates people to learn (Silvia, 2008; Deci, 1992). Thus, from the educational perspective the challenge is to get students interested. Interest is always dependent on content, and it is aroused as a function of the ‘interestingness’ of the event or object (Schraw, Flowerday, & Lehman, 2001). Interest cannot exist without a concrete or abstract object on which it can focus. This is essential to the Person-Object-Theory of Interest (POI), in which interest is conceptualised as a specific kind of relationship or quality of a person to the specific object (Krapp, 2002, 2005). This person-object relationship, which is subjective in nature, underlies changes over time. Instruction that aims at triggering and developing student interest may be successful
if it challenges the students’ initial subjective relationship with the topic or learning activity at both the emotional and cognitive levels (Krapp, 2005).

Interest is considered as “a unique motivational variable, as well as a psychological state that occurs during interactions between persons and their objects of interest, and is characterised by increased attention, concentration and affect” (Hidi, 2006, p. 70). In a classroom situation, a topic-specific situational interest could develop into a relatively-stable, predisposition-like interest with high personal relevance (so-called individual or personal interest) to “the whole spectrum of contents and actions that make up the curriculum of an entire educational program” (Krapp, 2005, p. 382), if aroused repeatedly and maintained (Hidi et al., 2004; Hidi & Renninger, 2006; Krapp, 2002). More specifically, Hidi and Renninger (2006) presented a four-phase model of interest development. The model encompasses the following phases: triggered situational interest, maintained situational interest, emerging personal interest, and well-developed personal interest.

In a classroom setting, triggered situational interest is sparked by environmental features and mainly supported externally, and may cause positive changes at both cognitive and emotional levels. Maintained situational interest is related to students’ continuous, externally-supported involvement with the topic. The maintained situational interest may transform into emerging personal interest in the topic or activity, but often students still need external support and encouragement to preserve and nurture that interest. If supported appropriately, students will then probably move to the fourth and final phase, which is called well-developed personal interest. Students in the fourth phase have a relatively enduring predisposition for being engaged in the activities that comprise a specific topic. If their interest is supported and sustained either through the efforts of others, or because of challenges or opportunities that a person acknowledges in a certain task, the four phases are considered to be sequential and distinct, representing a form of cumulative, progressive development (Hidi, 2006). However, this does not mean that identical support from others leads to all students in a class achieving a well-developed personal interest at the end of the teaching process. On the contrary, there are usually individual differences within a group of students (e.g. Guay et al., 2010). The development of interest-based motivation in school settings becomes an important tool for the emergence and stabilisation of individuals’ interest in certain domains and the stabilisation of a more general motivation orientation towards the domain.

The starting point is to trigger situational interest in the topic or learning activity and then help students to establish a personally-important relationship with or a personal interest in it. Triggering situational interest is partially under the control of the teachers by means of their organizing stimulating
Anni Loukomies

learning environments and activities. According to Silvia (2008), the evaluation of the ‘novelty and complexity’, and the evaluation of the ‘comprehensibility’ of an event are crucial to becoming interested in it. Palmer (2009) adds learning, choice, physical activity, and social involvement to the list of aspects that have an effect on situational interest. If successfully captured and maintained long enough, spontaneous situational interest may turn into more permanent individual interest (Hidi & Renninger, 2006; Krapp, 2002) that is related to an individual’s feelings or values (Schiefele, 1999), meaning that the content or context of the activity is considered interesting, enjoyable, or personally valuable by a learner.

The Person-Object Theory of Interest (POI), which is followed in this research in terms of the development of interest, agrees about the importance of the fulfilment of basic needs. The POI has borrowed the idea of the role of basic psychological needs from the SDT (for a review see Krapp, 2005; Krapp & Prenzel, 2011). The two theories, however, differ in the way they perceive the role of the three basic psychological needs in relation to the individual differences in interest and motivation development. The POI acknowledges that the cumulative experience from the feedback individuals have with respect to their basic needs “has an influence on both the short-term approach or avoidance tendencies that are relevant for establishing a situational interest, and the adaptation of the content-structure of an individual’s pattern of relatively stable preferences (e.g., individual interests)” (Krapp, 2005, p. 387). Thus, for POI the amount and the quality of need-related prior experiences are deemed to have an impact on the emergence, development, and stabilization of interest and interest-related motivation orientations.
5 Inquiry-based science teaching

Inquiry is a significant theme in the field of science education, and different approaches to inquiry in science education are presented, for example, Science Education and Science Teacher Education, edited by Hoveid and Grey (in preparation). This design-based research project was conducted following the principles of inquiry-based science teaching (IBST). ‘Inquiry-based’ in this project means that there are learning tasks encompassed in the procedure that are open in nature and that are not automatically followed by correct answers from the teacher or from the learning material. Students generate their own products, and the results of the project depend largely on how students accomplish the tasks during the project, and which aspects they want to emphasise.

When defining IBST, the framework constructed by Minner, Levy, and Century (2010) is followed. They argue that components of inquiry instruction are: formulating the question to be investigated, designing the investigation, collecting and organising data, drawing conclusions, and communicating the results. Inquiry science instruction, of course, also has the aspects of the presence of science content, student engagement with science content, and emphasis on student responsibility for learning, students’ active thinking and student motivation. The last three should take place within at least one of the components of inquiry instruction. A table presenting the construction of Minner & al. (2010) appears in Appendix 4. In this study, their definition is enriched with the view of Anderson (2007), who emphasises that student engagement with science content should encompass epistemologically authentic procedures like reasoning, posing of questions, and designing experiments, and, furthermore, social interaction and collaboration.

Traditionally, inquiry activities in science education are organised in laboratory settings. However, an industry site visit could also be organised according to inquiry teaching principles, with students formulating the question to be answered through interviews and observations, designing the visit, collecting and organising interview data and observations, drawing conclusions, and communicating how visit outcomes related to materials science content. The details of what students do during the sequence are described in the Chapter 7.

From the point of view of motivation, IBST has the potential of promoting the fulfilment of students’ basic psychological needs, because within IBST, motivating the students is not just an isolated and mechanistic phase in the beginning of the lesson that appeals to students’ curiosity; rather, support
for motivation is built into many phases of the instruction. As mentioned, supporting the fulfilment of psychological needs facilitates the internalization of the regulation of one’s behaviour (Ryan & Deci, 2002). In the framework suggested by Minner et al. (2010), the main categories of the aspects that an inquiry instruction ought to encompass are in accordance with the construction of the basic psychological needs proposed by SDT.

<table>
<thead>
<tr>
<th>Inquiry-based science teaching (IBST)</th>
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<tbody>
<tr>
<td>Student responsibility</td>
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<tr>
<td>Activating pre-existing knowledge</td>
</tr>
<tr>
<td>Communication</td>
</tr>
<tr>
<td>Support for the feeling of autonomy</td>
</tr>
<tr>
<td>Support for the feeling of competence</td>
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<tr>
<td>Support for the feeling of social relatedness</td>
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**Self-determination theory (SDT)**

Figure 2. Accommodating the characteristic features of IBST with the principles of the SDT (Juuti, Loukomies, & Lavonen, 2013).

Figure 2 illustrates how the connection between aspects of Minner et al.’s IBST and conditions for enhancing student motivation according to SDT is understood in this research. As the figure shows, there is potential within IBST instruction for generating autonomously-regulated behaviours. In more detail, students’ autonomy may be supported by not controlling the students externally with, for example, tests, but by letting the students’ voices be heard and taking their perspectives into account, offering the students choice, speaking in a non-controlling manner, allowing time for learning, and also offering them a meaningful rationale about why particular activities are undertaken (Reeve & Halusic, 2009). Students are allowed to take responsibility for their own learning, to set goals together with the teacher, to proceed according to their plans to reach the goals they set, and to plan activities individually or in small groups. The students’ competence, in turn, may be supported by choosing tasks with optimal difficulty levels, and offering students appropriate feedback. Students combine their previous knowledge with the new topics to be learnt, and tailor information structures that they can comprehend. Finally, students’ feeling of relatedness may be supported through collaboration and interaction in small groups that give them the feeling that
they are valued and respected (Niemiec & Ryan, 2009), or with the kind of interaction with the teacher that tells students that the teacher values them. Students may take part in group activities and support each other by discussions that include sharing, explaining, debating, and questioning ideas. Finally Inquiry instruction may help students engage in learning in real-life situations or in those that simulate real-life instances, and thus promote both interest and a sense of the subject’s relevance.
6 Out-of-classroom science learning

There is a wide variety of contexts for learning science which occur outside the normal classroom, as outlined in Learning Science Outside the Classroom, edited by Martin Braund and Michael Reiss (2004). Contexts for science learning encompass, for example, museums and science centres, zoos, farms and botanic gardens, and the outdoors in general, all of which they term the ‘actual’ world. Learning in museums and science centres has been widely researched (e.g. Anderson, Lucas, Ginn, & Falk, 2000; Falk & Storksdieck, 2005). Studying science in industrial sites is a less-commonly researched topic, and therefore this study has industry site visits as its focus.

Taking science classes outside the classroom may benefit many aspects of learning and motivation. Bransford, Brown, & Cocking (2000) and Donovan & Bransford (2005) emphasise the contextual aspect of learning new concepts. Any new concept is adopted as a part of one’s knowledge structure more effectively if it is introduced in a variety of contexts, in this instance the contexts of classroom and the real world. Braund and Reiss (2006, p. 1376) list five ways in which out-of-classroom settings can improve learning: improved development and integration of concepts, extended and authentic practical work, access to ‘big’ science and rare materials, improved attitudes to school science and social outcomes, more detailed collaborative work, and responsibility for learning. Furthermore, the approach of studying outside the classroom walls aims to make science learning more relevant and accessible to students (Braund and Reiss, 2004, p. 2), and encourage them to think more about science and its relationships with society and consequently with themselves (Braund & Reiss, 2006). An expert speaking enthusiastically about a particular scientific discipline may have a strong impact on students who are considering their future careers (Astin, Fisher, & Taylor, 2002). Even the simple fact that such visits are entertaining for most students provides an opportunity for developing their long-term interest.

Out-of-classroom studying also enables students to observe and participate in activities that would be impossible to do at school, and thus offers them an additional perspective on the topic in question. This is what Braund and Reiss (2006) refer as ‘big science’. Encountering science topics in a broader context than the traditional science class improves students’ scientific literacy, their awareness of how organizations respond to environmental requirements, and their awareness of the wide range of science-related career possibilities (Parvin & Stephenson, 2004). Parvin and Stephenson also report that their research with primary students shows that after an industry site visit,
students’ awareness of, for example, the raw materials used and processes involved in a given company, equipment, working environments, and scientific careers had become more accurate than before the visit. Students also began to see the links between science and industry, and they evaluated the site visit and related lessons as interesting.

Because significant effort is required when organising a site visit, it is important to profit from all the work that is done for the visit. Therefore, it is important that the visits cohere closely with the aims of the science curriculum, so that the visit and discussions and activities in the school laboratory complement each other in the best possible way. In his research, Kisiel (2005) found out that reinforcement or expansion of the curriculum were the main reason why teachers organised out-of-school visits. However, according to his review, he argues that many students go to visits unprepared, without a clear image of the aims of the visit. Furthermore, the teachers had not clearly adapted their roles in the preparation for and follow-up to the visit (De Witt & Osborne, 2007). A clear structure of the visit that includes thoughtful preparation and follow-up activities that facilitate the organisation of the new knowledge gathered during the visit will help take full advantage of the time spent on such a sequence.

When establishing collaboration between schools and industrial enterprises, both the science curriculum and the expectations of the industrial enterprise have to be considered. Industrial enterprises have various reasons for engaging in school outreach, from public relations to future recruiting initiatives. Countries like Finland rely heavily on the industrial sector, and future experts and other kinds of employees will be needed. Inviting student groups for visits is a good opportunity to promote knowledge concerning a given industrial sector and careers related to it. Because companies have their own aims when inviting student groups to visit them, and some of them even have ready-made plans for such visits, it is important that the teacher of a visiting group keeps the curricular aims clear and also informs the company of those aims. Otherwise, there may not be suitable occasions for students’ data gathering, or the visit may focus on irrelevant aspects from the point of view of the topic to be studied. It would be best if a teacher visits the company in person before the official site visit in order to help with planning; the teacher should also remember to gather feedback from the students and share it with the company. In their case study conducted in New Zealand, Brunton and Coll (2005) have identified some possible barriers to school-industry links, centred around resources, logistics, and security and safety issues. All these obstacles may be diminished or overcome by contacting the company in the preparation phase and by careful joint planning with company personnel.
Based on the literature review of research on learning science in the out-of-classroom setting, it is concluded that industry sites are a less commonly-examined context. The contribution of this study to this area of research is a teaching sequence that is clearly structured but allows modifications based on particular teachers’ needs, that is clearly integrated with the curricular aims, and that is based on theory-based knowledge about motivation and interest. The detailed structure of the site visit teaching sequence and the intended learning outcomes of it are described in the next chapter.
7 Industry site visit teaching sequence: An overview

This chapter describes what was designed based on the literature reviewed in Chapters 1–6. The structure of the site visit teaching sequence is outlined in order to offer the reader an understanding about the context of this research, and to offer a view on what the students actually did. The design process (with several implementations of the teaching sequence), the theory-based conjectures embodied in the design that aimed at enhancing students’ motivation, the scientific content and intended learning outcomes of the sequence, and the decisions that were made during the design process are described and scrutinised in depth in Chapter 9.

The designed site visit teaching sequence offers an alternative and flexible way of teaching science. In this particular case, it is related to materials science content, but it can be applied to other science content as well. It is described in detail in the student book prepared for the sequence (Lavonen et al., 2009) and in the teacher guide for the sequence (Loukomies et al., 2009). Preparing that material has been essential to this study.

The sequence consists of:

- **Preparing phase**: inquiry and classification activities for helping students to understand the science content encountered in the site visit, searching for information on the Internet, deciding about the perspective of the report, preparing questions to for company personnel;

- **Site visit phase**: observations, interviewing company personnel, gathering data;

- **Processing phase**: preparing articles based on the data, employing the process writing technique, concept-mapping activities with, for example, Cmaptools, in order to get an structured view of the topic.

Before the visit the students prepare themselves by searching for information about the company on the Internet and the use and production of materials at the site. Using information and communication technologies (ICT) is considered an interest-awakening aspect in the learning environment (Hidi & Renninger, 2006). Students also prepare questions that will be sent to the company and plan interview questions concerning manufacturing processes or
material-science occupations and careers at the site. In this phase, there are
many decisions that students can make, and it encourages students’ feelings
of autonomy. Students report on the visit by writing articles about an aspect
that holds particular interest for them. When preparing their writing tasks,
students first get acquainted with the company and its specific branch of
industry through the company’s web presence, then plan the perspective of
their own articles, and finally decide about a specific focus for their topic.
Topics chosen by students may be, for example, ‘materials used in produc-
tion’, ‘raw materials and their origins’, ‘quality control’, ‘processes at the site’
or ‘different occupations and the education needed for those occupations’.
From the point of view of learning materials science, students conduct classi-
fication tasks to orient themselves towards their topic. An example of the
allocation of time resources recommended in the student book (Lavonen &
al., 2009) is presented in Chapter 9.

Students also conduct inquiry tasks in order to prepare themselves for en-
countering the science content in the visit. Given that this design research
process took place in the materials science context, the inquiry tasks were
also related to the properties of materials. The activities were conducted in a
Predict-Observe-Explain (POE) sequence. The POE strategy was developed
by White and Gunstone (1992) to uncover individual students’ predictions
about a specific event, and their reasons for making those predictions. In the
sequence, POE is used within a science inquiry activity and guided via a
student worksheet. The POE strategy can be used for determining students' initial ideas, existing models, or internal representation, providing teachers
with information about students’ thinking, generating discussion, motivating
students to want to explore the concept, and designing investigations. The
POE procedure is described in detail in Chapter 9. In the inquiry activities of
this sequence, models of materials were emphasised.

For the visit, students have a task much like investigative journalist’s. Be-
fore the site visit, they familiarise themselves with the journalist’s job and
study how to write articles. They collect data for their articles by conducting
short interviews during the visit. The visit starts with an introduction to the
activities of the company. A visit to the factory, with students divided into
small groups, then follows. Finally, the students have the opportunity to in-
terview a variety of staff members in small groups. During the site visit, the
students take notes about what they see and hear and interview personnel
whose expert knowledge is relevant from the point of view of the topic of the
students’ articles.

After the site visit, students write articles about certain aspects of the visit
in collaborative groups, using a process writing technique that emphasises
peer feedback. The writing process takes place within weeks, and encom-
passes a large number of different phases, from choosing the topic and perspective, compiling interview questions, conducting interviews and making notes, browsing the web in order to acquire information to enrich the written product, writing the text, defining the language, and ending with the appearance of the article; the students move through all the phases in collaboration with peers. The writing task helps students to organise the new knowledge they have gathered during the sequence.

The language and literature teacher explicitly teaches what an article is like as a text type, and what its style, language, and appearance should be. Content, structure, and form are emphasised. The text should encompass the student’s own observations and discussion, and multiple information sources, such as interviews, information from the web and pictures, should be used in a fluent way. The appearance of the article should correspond to in article in a magazine, meaning that the article should encompass the following parts: main heading, introduction, division into paragraphs, possible subheadings, pictures and captions, possibly figures, charts, and drawings, and the names of the authors. The writing style should be matter-of-fact, but the style is not solely on the students’ responsibility, as during the writing process the teacher gives comments and feedback, and thus the style and spelling are shaped collaboratively. If the style and structure are emphasised appropriately in the instruction, the end results should be texts that really are articles and not traditional school reports.

After presentations of the articles, students’ knowledge acquisition and the industry site visit as a whole are assessed through evaluation discussions and evaluation questionnaires (Lavonen et al., 2009); feedback is sent to the company contact person as well. The preparation phase enables the students to scrutinise their pre-conceptions about the topic, and processing helps them to develop their metacognitive skills, as feedback is offered to them. Both of these aspects are essential if learning is to be effective (Donovan & Bransford, 2005). The science teacher and the language arts teacher must work in close collaboration during the sequence.
8 Data collection methods

The research task in this study was to examine which particular aspects of the design have appealed to particular students and enhanced their motivation and interest, and what scientific content students have learnt within the project. The mixed-methods approach was employed when collecting data in order to answer the research questions. Because the same data is related to different substudies, the data collection methods are introduced before reporting the substudies.

During this DBR project, a site visit teaching sequence was designed, and a pilot test, two different cycles of design, implementation and refinement, and a final trial were conducted. Lower secondary school students (aged 14–15 years) participated in the study in all cycles. After each cycle of implementing the designed teaching sequence, several sets of data were collected in order to answer the research question, using multiple sources of evidence (video recordings, student and teacher interviews, meeting memoranda, and questionnaires) according to the accepted principles of case study research (Yin, 1994). All the cycles included students from different schools. The empirical data encompasses the experiences and views of students, teachers, and external evaluators. Data collection is a means of formative evaluation of any DBR project, as the data were analysed within the project before moving to the next cycle. In addition, the data was also analysed retrospectively, once the entire project was completed. The conclusions, which emerged from the analysis of the data and evaluations of the process, guided decisions about redesigning elements of the process. Table 1 describes the data collection methods employed during the designing and testing activities.

Table 1. Data collection methods during the cycles.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Data</th>
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<tbody>
<tr>
<td>Pilot Cycle, Okmetic Plc, 2007</td>
<td>- Students’ evaluation questionnaire, Likert scale (N=21)</td>
</tr>
<tr>
<td></td>
<td>- Students’ evaluation questionnaire, open questions (N=21)</td>
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<tr>
<td></td>
<td>- Video recordings of the planning phase and the visit</td>
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<tr>
<td>First Cycle, Vaisala Plc, 2008</td>
<td>- Video recordings of the planning phase and the visit</td>
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<td></td>
<td>- ESIAQ (N=14)</td>
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</table>
8.1 Evaluation of Science Inquiry Activities Questionnaire (ESIAQ)

The Evaluation of Science Inquiry Activities Questionnaire (ESIAQ)1 (Appendix 1) was employed in this research in order to track the teaching sequence-related change in students’ motivation towards school science. It is based on the ‘Intrinsic Motivation Inventory’ (IMI), a multidimensional measurement for assessing participants’ subjective experience related to a target activity, that has been used widely and that is internationally validated (e.g. Deci, Eghari, Patrick, & Leone, 1994; Ryan, 1982). The questionnaire is available on the official web site of the self-determination theory. Originally, the IMI was developed to be used in intrinsic motivation laboratory experiments, in which participants have worked on an interesting activity under some experimental condition. In the IMI, their levels of interest and enjoyment, perceived competence, effort, value and usefulness, felt pressure and tension, and perceived choice while they were performing the activity are assessed. The criterion for inclusion of items on subscales is a factor loading of at least 0.6 on the appropriate subscale and no cross loadings above 0.4 (www.selfdeterminationtheory.org/questionnaires).

When converting the wording in the questionnaire to make it suitable for science education research, the questionnaire was also renamed Evaluation of Science Inquiry Activities Questionnaire (ESIAQ). This research was not conducted in an experimental laboratory setting, and therefore it was not possible to distinguish the ‘activity’ under scrutiny explicitly from other activities that students conduct during the school day. In the Finnish transla-

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1 ESIAQ is based on Intrinsic Motivation Inventory (IMI), http://www.psych.rochester.edu/SDT/measures/intrins.html
the term that was used instead of ‘activity’ was ‘science inquiry activity’. In this research study, before the sequence ‘science inquiry activity’ meant typical science learning activities, like practical school laboratory work. After the sequence, however, the term included the designed site visit teaching sequence. The students were advised what was meant by ‘science inquiry activity’ both before and after the teaching sequence. The Finnish translation was conducted in an iterative process. First, I translated the questionnaire into Finnish. Then another researcher translated the Finnish version back to English, and the original and the translated English versions were compared, and required revisions were conducted. The items within subscales were randomly ordered in the questionnaire, and the word order of some questions was reversed.

The ESIAQ uses a seven-point Likert scale (1=‘item in my case is not at all true’ through 7=‘item in my case very true’). Ordinal scales, like Likert’s, have been widely used in asking for opinions and attitudes. The strength of a Likert scale is in the subtlety of the responses (Cohen, Manion, & Morrison, 2007). Measurements developed for interval scales, for example counting means and standard deviations, may be employed for ordinal Likert scale measurements (Metsämuuronen, 2006). In the beginning of the analysis, the scores of the reversed items were reversed by subtracting the numeric item response from 8. Sum variables were calculated for each subscale through calculating mean values for the responses of each student in this scale. The values of each subscale were distributed normally and therefore a paired samples t-test was used for comparing the mean values of students’ answers for certain subscales at two points of time, namely in the pre- and post questionnaires, the null hypothesis being ‘there is no significant difference in the means of the ESIAQ subscales in the pre- and post questionnaires’.

In Chapter 9, the ESIAQ data is considered one cycle at a time, whereas in Chapter 10, which concerns student motivation, the samples from cycles 1 and 2 have been combined. Therefore the means, standard deviations and t-values differ from one substudy to another.

The instrument measured participants’ interest and enjoyment (7 items), perceived competence (6 items), value and usefulness (7 items), perceived choice (7 items) and relatedness (6 items). Besides these, five items concerning students’ effort related to the activity and five items concerning experienced tension or pressure during the activity were included in the questionnaire. However, the first five subscales cover the theory-based features that were included in the design (support for students’ feeling of autonomy, competence, social relatedness and feeling, and value related interest), and thus subscales of effort and pressure and tension were excluded from the statistical analysis of the ESIAQ. In order to evaluate the reliability of the meas-
urement, Cronbach alphas were calculated for each subscale of the ESIAQ. First the data from cycles 1 and 2 were treated separately for the purposes of Chapter 9, and then both cycles together for the purposes of Chapter 10. The alphas were typically between 0.6 and 0.9. Two sum variables yielded very low alpha values. It may be due to sensitivity of the small sample.

### 8.2 Academic Motivation Questionnaire (AMQ)

The Academic Motivation Questionnaire (AMQ)\(^2\) (Appendix 2) was employed in this research in order to distinguish students with different motivation orientations. It is based on the Academic Self-Regulation Questionnaire (SRQ-A) developed by Ryan and Connell (1989), and the Academic Motivation Scale (AMS) developed by Vallerand et al. (1992); both were based on SDT theory (Deci, Eghrari, Patrick, & Leone, 1994; Ryan, Koestner & Deci, 1991). Three new items were designed for measuring amotivation through a deductive approach (Burisch, 1984). Thus, the final instrument consisted of 29 items and assessed the participants’ amotivation (4 items, \(\alpha=.95\)), external regulation (4 items, \(\alpha=.66\)), introjected regulation (4 items, \(\alpha=.67\)), identified regulation (5 items, \(\alpha=.80\)), and intrinsic motivation (12 items, \(\alpha=.81\)). The instrument was written in the native language of the participants and responses were provided on a 7-point Likert scale (1=‘strongly disagree’ and 7=‘strongly agree’).

Students answered the AMQ before the teaching sequence in cycles 1 and 2. The aim of using the questionnaire was to categorise students based on their motivation orientation as understood by SDT. In order to discover similarities that likely correspond to different types of motivation orientations, K-means cluster analyses were conducted. K-means cluster analysis begins with defining the initial cluster centres; each observation is connected with the nearest cluster centre, and the centres become more specific with new observations. The iterative search for cluster centres continues until new observations no longer cause any change in the situation (Metsämuuronen, 2006).

In this research, three different cluster analyses were conducted in cycles 1 and 2, presenting three, four and five clusters. Examination of the output from each of those analyses led to the choice of a three-cluster solution in both cycles. This solution yielded the most interpretable cluster structure. It would have been ideal to have five clusters, one representing each SDT-based motivation orientation (amotivation, extrinsic, introjected, identified, identified, 

\(^2\) AMQ is based on the Academic Self-Regulation Questionnaire (SRQ-A) and Academic Motivation Scale (AMA), http://www.psych.rochester.edu/SDT/measures/intrins.html.
integrated and intrinsic motivation orientations). However, in the five- or four-cluster solutions there were two or one clusters, respectively, for which no particular motivation orientation could be distinguished. For example, perhaps because of the wording of the AMQ, the introjected regulation cluster did not reveal itself even in the five-cluster solution. In order to specify the meaning of each cluster, sum variables of the subscale item’s means of the participants who were classified in each cluster were calculated. Participants usually have higher mean scores in their ‘own’ cluster, compared to other clusters and the total mean score of all participants.

The clusters were named on the basis of the subscale that had higher scores than others. In the sample, the names ‘identified/intrinsic’ (autonomous), ‘amotivation’, and ‘external/identified’ (controlled) were given to clusters 1–3, respectively. This distinction is in line with SDT, as it roughly distinguishes the different ways of being motivated along the intrinsic/autonomous-controlled/extrinsic/amotivation continuum. However, the fact that the clustering did not place students into a certain motivation orientation category may suggest that students are not generally reducible to only one ‘motivation orientation’. The student’s patterns do not automatically follow the categories that emerge from theory, and therefore students’ answers reveal a more detailed picture of their particular motivation orientations. They may have features of more than one motivation orientation at the same time.

However, the distinction between autonomous and controlled regulatory styles and motivation orientations is important from the point of view of the benefits of an autonomous regulatory style for an individual (for more detail, see Chapter 4). As the data gathering was a primary tool for redirecting the design, the clustering and the subsequent interviews were conducted immediately after each cycle. This means that students are categorised based on their motivation orientations relative to their own groups in that particular cycle, and not in relation to the group comprised of the combined samples from cycles 1 and 2. The cluster structure might have been different if all 29 students were treated together as one group. In other words, because of this organisation of the groups, there are students that end up located in the same category of amotivation, but as a consequence of different cluster analyses.

The original questionnaires used in this research were created in the English language. An iterative translation technique was used to translate the elements of the study from the original English version into Finnish language (Brislin, 1986). The measures were translated from English to Finnish by one researcher. Another researcher then translated the Finnish version respectively back into English. These versions were then compared with the origi-
nal and the appropriate corrections were made to the Finnish version until all the discrepancies were eliminated.

8.3 Interviews

Retrospective interviews with individuals that have recently developed a new topic-related interest have been proposed as a methodological tool to explore the process of interest development at the intra-individual level (Krapp, 2005). Interviews enable students to express how they regard situations from their own points of view, and while they remain somewhat controlled, they give space for spontaneity (Cohen, Manion & Morrison, 2007).

Students (aged 14–15) were interviewed in the two cycles that were coordinated by the researchers. Students were selected for the interviews based on their distance from the cluster centre: the aim was to select a student near the cluster centre. The cluster analysis of the AMQ aimed at grouping the students on the basis of their motivational profiles, and furthermore, the aim was to interview students from different motivational categories, in order to hear opinions of amotivated students and those with controlled and autonomous orientations. This was not possible in every case, largely for practical reasons (some students for example were not present at school at the time of the interviews). In order to strengthen and verify the selection, Tables 2 and 3 presents the means of each selected student in the five subscales. Following the above procedure, three students were selected for the interviews. The time between the implementation of the sequence and the interview was kept as short as possible, and that is why the groups from cycles 1 and 2 were treated separately in this phase of the research. In other words, the cluster analyses were conducted right after the cycle, and the students were interviewed no more than two or three weeks after the teaching sequence had been completed.
Table 2. Subscale mean scores of the selected participants from the first cycle of the design research. Bolded numbers show the mean score on which participant’s classification is based. Italicised numbers show the cases where the mean is high also in another subscale.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Amotivation</th>
<th>External Regulation</th>
<th>Introjected Regulation</th>
<th>Identified Regulation</th>
<th>Intrinsic Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN_02</td>
<td>5.00</td>
<td>2.75</td>
<td>3.00</td>
<td>2.25</td>
<td>1.92</td>
</tr>
<tr>
<td>FN_06</td>
<td>1.25</td>
<td>5.00</td>
<td>2.75</td>
<td>5.40</td>
<td>4.50</td>
</tr>
<tr>
<td>FN_09</td>
<td>1.00</td>
<td>3.00</td>
<td>2.75</td>
<td>5.00</td>
<td>4.42</td>
</tr>
</tbody>
</table>

Table 3. Subscale mean scores of the selected participants from the second cycle of the design research. Bolded numbers show the mean score on which participant’s classification is based. Italicised numbers show the cases where the mean is high also in another subscale.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Amotivation</th>
<th>External Regulation</th>
<th>Introjected Regulation</th>
<th>Identified Regulation</th>
<th>Intrinsic Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN_07</td>
<td>6.00</td>
<td>3.75</td>
<td>2.50</td>
<td>2.20</td>
<td>1.75</td>
</tr>
<tr>
<td>FN_11</td>
<td>4.00</td>
<td>5.25</td>
<td>2.50</td>
<td>4.80</td>
<td>2.17</td>
</tr>
<tr>
<td>FN_15</td>
<td>1.25</td>
<td>5.75</td>
<td>4.50</td>
<td>6.20</td>
<td>3.75</td>
</tr>
</tbody>
</table>

The interviews were semi-structured, meaning that a general structure is set up by the interviewer by deciding in advance the topics to be covered and the main questions to be asked. The detailed structure, meaning the order of the topics and additional clarifying working questions was determined during the course of the interview, depending on what emerged in the expressions of a particular interviewee. The interviewee had a freedom to decide how much to say and how to express it (e.g. Drewer, 2003). Approximately half of each interview concerned motivation and half concerned students learning. Thus, both of the dissertation’s large themes were discussed in one interview, and, of course, the criteria of selecting students for the interviews were the same concerning both topics. The interview situation was informal and conversational. The interviews were individual and were conducted in the mother tongue of the participants. The aim of the interviews was to reveal the features of the sequence that students with different motivation orientations identified as triggering their interest in learning science.

This study is concerned about students’ motivation and the possibilities of enhancing motivation by supporting the fulfilment of students’ basic psychological needs and taking advantage of their interest. The questions were planned to reflect adequately the aims of the research and the variables to be measured (Cohen, Manion, & Morrison, 2007). The interview protocol was
developed according to five motivational axes of the sequence: the most interesting or motivating issues (interesting content), possibilities of influencing the way things were done (support for autonomy), possibilities for collaboration with classmates (support for social relatedness), possibilities of feeling competent during the learning tasks (support for competence), possibilities of revealing the feelings of interest and enjoyment that emerged within the student groups (enjoyment). The interview protocol started with asking students about their experiences and opinions about the site visit teaching sequence at a general level. The following questions reflected aspects related to the motivational and interest-related features embodied in the sequence (or the variables to be examined). When designing, these features were considered with wording such as ‘students’ feeling of autonomy will be supported...’. However, it was obvious that students aged 14–15 cannot be asked about their feelings of autonomy using such difficult concepts, and thus the questions were formulated in order to be more easily understood by the students. For example, the fulfilment of the students’ need for autonomy was clarified by asking ‘What kinds of possibilities did you have to influence the way things were done during the site visit teaching sequence?’. The fulfilment of their need for social relatedness, was clarified by asking for example ‘What kinds of possibilities to work together with your classmates did you have during the site visit teaching sequence?’ The full interview questions are presented in Appendix 3. The focus was on how students reflected the fulfilment of their three basic psychological needs. Questions answered with a simple, immediate affirmative or negative were followed by the question ‘why?’ or a request to explain in more detail.

Concerning the second part of the interview, namely students’ reflections on what they remembered about the content of the teaching sequence, the interview protocol was based on the aims of the sequence. The interview questions in this part reflected the intended learning outcomes and dealt with materials encountered during the visit, products that were manufactured from these materials, and careers and professions that were related to the company. There also were additional questions concerning students’ view of their own mind maps before and after the visit.

The interviews were recorded, transcribed completely, and then analysed. The analysis of the interviews followed the principles of theory-driven content analysis (Patton, 2002; Tuomi & Sarajärvi, 2002), as the categories for the analysis deductively emerged from the theory. According to the interview protocol, after a preliminary reading of the transcriptions, a theme was defined as a unit of analysis. Themes concerned the basic needs and units of analysis were coded on the grounds of the basic need they illustrated. The codes were AU (support for the need of autonomy), CO (support for the need
for competence), SR (support for the need for social relatedness), FEE (support for feeling-related interest), VALUE (support for value-related interest), CON (support for content-related interest) and CNTX (support for context-related interest). The last four are aspects of interest. There were also more specific subcategories in the main categories.

**Table 4.** Interview analysis categorization

<table>
<thead>
<tr>
<th>AU</th>
<th>AU1 Active co-planning of a teaching unit (or a large learning activity) by students; AU2 Activities that support a feeling of autonomy or situations where a student could make choices on how to perform alone (including use of ICT); AU3 Activities that support a feeling of autonomy or situations where students could make choices in a small group on how to perform in small groups; AU4 Use of student-centred learning methods;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>CO1 Activities that support a feeling of competence or success in performing a task alone (including use of ICT), or tasks which are possible for most students to solve, or there are differentiation in the task according to students’ abilities; CO2 Activities (in a small group) that support a feeling of competence or success in performing a task (including use of ICT); CO3 Use of constructive evaluation methods (self and group evaluation);</td>
</tr>
<tr>
<td>SR</td>
<td>SR1 Activities in small groups that support feeling of social relatedness (feeling that students are part of a successful team or feeling of being close to peers when working towards the goals of the activity), including use of ICT; SR2 Activities that support the feeling of trust and respect amongst peers;</td>
</tr>
<tr>
<td>FEE</td>
<td>FEE1 Activities that awaken curiosity; FEE2 Activities that hold attention; FEE3 Activities that are fun or enjoyable to perform;</td>
</tr>
<tr>
<td>VALUE</td>
<td>VALUE1 Activities that awaken value-related components of interest, such as activities with some value from the point of view of science learning (benefit) or future studies or career, or activities that support the feeling of the importance of working; VALUE2 Activities that value students’ own ideas;</td>
</tr>
</tbody>
</table>
CON  CON1 Activities that support the feeling that properties of materials are interesting content;
CON2 Activities that support the feeling that learning science in a material science context is interesting;

CNXT  CNXT1 Interesting context;

In the second part of the interview, themes that were selected as units of analysis were coded on the grounds of the aims of the sequence. The codes were occupations, materials and products. The results of that part of the interview are discussed in Chapter 10.

The interviews took from twenty to twenty-nine minutes, and they generated eight to thirteen pages of transcripts each. I read the students’ answers several times. First, the interviewees’ utterances were associated with the main category features mentioned above. Second, reduced expressions in English were composed after distinguishing the relevant issues from the ones focusing on something else, and encoded with the relevant category code in the analysis table. Students’ word-for-word quotations, the English translations of the word-for-word quotations, and the coded reduced expressions of these quotations were arranged in the analysis table. Finally it was confirmed that the categorisation agreed with the original Finnish expression.

Both teachers from cycles 1 and 2 were also interviewed. They were asked about same themes than the students, but the perspective was the teachers’ interpretation about how the motivation- and interest-supporting features embodied in the sequence appeared in the implementations. After the final trial, six participating teachers were interviewed with a similar protocol as in previous cycles.
9 Design and development of the site visit teaching sequence Materials Around Us: Description of an iterative process

In this chapter, the iterative design and development process of an inquiry-based industry site visit teaching sequence Materials Around Us is described. The aim of this chapter is to introduce the design process, especially the embodied theory-based conjectures, to analyse retrospectively the decisions made within actions and state the rationales for them. In addition, I present and discuss what may have been learnt about introducing materials science in schools using an industry site visit as a pedagogical approach.

The design process took place in years 2007–2009 and was conducted according to the principles of DBR (DBRC, 2003; Juuti & Lavonen, 2013). The research literature concerning the quality standards of DBR on the one hand and literature concerning students’ motivation and interest on the other constitute the research literature on which this chapter is based. The literature that constitutes the grounds of the design, namely research concerning student motivation and interest, inquiry-based science teaching, and science learning outside the school context is covered in Chapters 4, 5, and 6. The quality criteria of the DBR and how this research project met these criteria are considered in detail in Chapter 12.

To ensure the quality of design and research in a DBR project, certain aspects need to be taken into account. From the design point of view, the novelty and usefulness of the design solution were considered critically, from the point of view of organising site visits in Finland in the context of science education. There is a long site visit tradition in Finland, involving especially visits to science centres and museums, but also to industry sites (Kuitinen & Meisalo, 1988). Site visits are highly recommended in the National Core Curriculum that now also includes entrepreneurship education as an intercurricular issue (Framework Curriculum for the Comprehensive School [FCCS], 1994; National Core Curriculum for Basic Education [Finland, NCCBE], 2004), but according to students, they are seldom well-organised (Juuti & al., 2010). The companies also benefit from such visits. Many of the industrial sites, which are open to visits, have either by themselves or with the input of teachers developed visitor programs or student materials corresponding to school subjects. The common characteristic among all programs and study materials is that they guide students to familiarise themselves with the site before the visit, gather information during the visit, and work with the new
Anni Loukomies

information afterwards. This process follows the ideas of Storksdieck (2001), who argues that the student preparation phase and examination of students’ prior knowledge and attitudes and a follow-up are essential to connect the visit successfully to the curriculum. Despite the emphasis on visits in science education, based on Finnish PISA 2006 Scientific Literacy Assessment data, the teaching methods and learning materials in Finland are notably traditional and emphasise a combination of teacher-delivered instruction and student-conducted experiments (Lavonen & Laaksonen, 2009).

The demands of theory-based design (Edelson, 2002) were taken into account by grounding the design in literature that concerns inquiry-based science teaching, motivation, interest and learning about the properties of materials. In order to understand Finnish students’ interest in science and science-related careers in more detail, two large surveys were conducted in Finland before this project (for details, see Lavonen, Byman, Uitto, Juuti & Meisalo, 2008; Lavonen et al., 2008). According to these surveys, student interest in science and science-related occupations may be increased by: choosing contexts emphasising societal issues in science education and the role of human beings in science-related situations; choosing teaching methods, such as a site visit, that help students to become familiar with the use of science in society, tailoring learning activities that emphasise students’ collaboration and feelings of autonomy and engagement, and demonstrating the particular characteristics of occupations. This valuable information has been taken into account when designing and developing the sequence and the learning material related to it.

The designing process took place as a shared activity of researchers and teachers in order to generate solutions that facilitate more effective ways of teaching and studying (Juuti & Lavonen, in press). The iterative design process, meaning the planning and reflection sessions with researchers and teachers and implementations of the sequence in different cycles, was carefully documented and formatively evaluated throughout the whole project, and retrospectively analysed. Retrospective analysis of formative evaluations enabled tracking the changes that were made during the process, and offered justifications for these changes. As a result, some new knowledge about student motivation in the context of science education and a transferable design solution, an inquiry-based site visit teaching sequence, were generated.

9.1 Research question of the first substudy

The aims of designing and refining the teaching sequence and enhancing students’ motivation and interest in science learning and related occupations are intertwined, because information about the fulfilment of the aims of the
teaching sequence also offers insight into the success of the operationalization of the theoretical constructs and, furthermore, the design per se. The formulation of the research questions encompasses both aspects of the project, the aspect of designing a teaching sequence, and the aspect of students’ motivation. The research question is:

How was the site visit teaching sequence designed and revised during an iterative process according to the theory-based conjectures about motivation and interest, and what did the analysis of these conjectures reveal?

The research question of this substudy is answered on the basis of the formative evaluation that took place during the project, e.g., feedback of external evaluators and participant teachers, and by analysing students’ interviews.

9.2 Designing the site visit teaching sequence by embodying theory-based conjectures

The starting point of the design process was updating the model for an activity-based industrial site visit (Kuitunen & Meisalo, 1988) to fit with the materials science context, and to include motivation- and interest-supporting features, based on relevant research based knowledge. The research-based features are conjectures that are embodied in the design (Sandoval, 2004). The process of embodiment specifies how high-level theoretical conjectures appear concretely in the design (Sandoval, 2013). In this research, conjectures about motivation, interest, and science content learning were embodied in the procedure of the site visit teaching sequence and materials related to it. Research of these embodied conjectures then uncovers aspects related to the effectiveness of the designed intervention that help improve it (Sandoval, 2004). Besides the requirement of being derived from theory, a key feature of embodied conjectures is that they may lead not only to the improvement of a particular design solution but also can potentially lead to theory refinements (Sandoval, 2004, p. 215), and, in this particular case, they may generate new knowledge concerning the relationship between motivation, interest, and science studying. In other words, DBR strives to to make the theoretical assumptions explicit testable. Designing educational interventions is not simply conceiving projects and seeing if they work, but it is a theoretical activity (Sandoval, 2004). In this study, the conjectures embodied in the design emerge mainly from the self-determination theory of motivation (e.g. Ryan & Deci, 2002) and the POI theory of interest (e.g. Krapp, 2002).
The original Kuitunen-Meisalo model emphasised student activity, in contrast to traditional sightseeing-tour visits. The model was introduced in the Eighties but it was not widely employed. Because study visits are recommended in the National Core Curriculum, visits are organised at schools even without this teaching sequence. However, there are distinctions between this teaching sequence and ordinary study visits. The designed teaching sequence is a structured whole that encompasses preparation, the visit itself, and elaboration afterwards. The philosophy of IBST actualises in the students’ role, as they actively plan the data gathering, collect the data, and process it afterwards. The integrative approach between science and language arts gives a special characteristic to this project. Additionally, the conceptualisation of the means that may help to enhance students’ motivation distinguishes this project from other visit techniques. Besides its materials science content and the motivation- and interest-promoting features, the use of ICT in the acquisition of information and inquiry orientation are different from what was introduced in the original version of the model. When designing the prototype for this project, experiences gathered during several science teachers’ professional development projects (Juuti, Lavonen, Aksela, & Meisalo, 2009; Lavonen, Juuti, Aksela & Meisalo, 2006; Lavonen, Jauhiainen, Koponen, & Kurki-Suonio, 2004) were used as resources. Furthermore, the principles of pragmatism-based DBR as described in Juuti & Lavonen (in press) were employed, and the designing of the teaching sequence was conducted in collaboration with teachers. Their views, beliefs, and habits were seriously taken into account. In practice, reflective discussions with teachers while developing the teaching sequence were emphasised. The core challenge when designing the teaching sequence was implementing the aim of designing a teaching sequence that could be used at any school in Finland or even elsewhere in Europe, despite differences in school location or the number of students in the class. An outline of the pilot version is presented below in Table 5. The structure of the prototype is based on the Kuitunen and Meisalo (1988) model.
Table 5. Structure of the pilot site visit sequence.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Theoretical rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Advance planning by teachers</td>
<td>General level planning by science teacher and career counsellor.</td>
<td></td>
</tr>
<tr>
<td>2. Preparatory visit by the teacher</td>
<td>Teacher plans the visit with the company contact person.</td>
<td></td>
</tr>
<tr>
<td>3. Students’ preparation</td>
<td>Co-planning the visit. Formulating study groups, learning about the company by using web resources, formulating questions and sending them to the company. ICT is used in this phase.</td>
<td>Co-planning supports student autonomy. Collaborative and student-centred activities support student autonomy, competence, and relatedness.</td>
</tr>
<tr>
<td>4. The site visit</td>
<td>Introduction and sightseeing.</td>
<td>Collaborative and student-centred activities support student autonomy, competence, and relatedness.</td>
</tr>
<tr>
<td>5. Student group reports</td>
<td>Students prepare and present the reports. ICT is used in this phase.</td>
<td>Collaborative and student-centred activities support student autonomy, competence, and relatedness.</td>
</tr>
<tr>
<td>6. Feedback with site representatives, evaluation of the reports</td>
<td></td>
<td>Evaluation and informal discussions help students recognise their strengths and increase their feelings of competence.</td>
</tr>
<tr>
<td>7. Collecting ideas for future visits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It was concluded, on the grounds of the reviewed literature, that students’ motivation and interest may be promoted through selecting activities that
support their feelings of competency, social relatedness, autonomy, and interest in science-related topics. Firstly, activities that are intended to support students’ feeling of autonomy encompass student-centred methods; students are offered choice and actively participate the planning of studying activities. The structure for studying is offered by the teacher. The intended outcome of studying is an article with appropriate scientific content related to a particular branch of industry, and within this structure, students have plenty of decisions to make including the focus, preparation, data collection, working order, and the appearance of the output. Even responsibility for the organizational tasks related to the visit may be allocated to the students at appropriate levels. Additionally, inquiry tasks enable students to act autonomously. Structure is an important aspect here, because without sufficient structure, students may be adrift with such an open-ended and multifaceted sequence. Structure makes the learning environment predictable and helps students to regulate their academic behaviours more efficiently. However, guiding should be done in an autonomy-supporting way, or structure may be experienced as controlling (Guay, Ratelle, & Chanal, 2008).

Secondly, support for students’ feeling of social relatedness was included in the design through the selection of collaborative learning activities and co-planning, which help students to feel close to their peers and to help them develop trust in each other. Students’ feelings of social relatedness is also supported through informal discussions between the teacher and the students. Almost all activities within the teaching sequence are conducted in collaborative groups in which there are tasks for all group members. Students may organise the division of labour in the groups themselves. It is up to the individual teacher’s knowledge about the dynamics of a certain class whether students are allowed to conduct the division into groups themselves or whether the teacher assists with that task. Working actively with an interesting topic may facilitate students getting to know each other better and even make friends.

Thirdly, support for students’ feeling of competence was included in the design through the selection of constructive evaluation methods, like self- and group-evaluation, which help students recognise their skills, through support for the feeling that an activity has some value or use for the student, through help alongside the process of gathering data and elaborating it in the article writing task, and in the evaluation discussions. To support students’ feeling of the value of their activities, it is highly recommended, for example, that students’ articles are published in some fashion. The activities at the industry site are organised in a way that enables equal discussions between the students and the experts at the site. The students are responsible for their own questions, and the teacher does not guide the discussions. Throughout
the entire sequence, the teacher’s formative feedback should guide and redirect students’ activities.

Finally, interest research suggests a means of sparking students’ situational interest, namely the novelty and complexity of a certain phenomenon (Silvia, 2008). Students’ interest is supported by offering them novel experiences and multifaceted and even surprising phenomena to observe in an authentic context. Feeling-related valence of interest is supported through selecting appealing activities, e.g., inquiry tasks and ICT activities. Additionally, the value-related valence of interest is supported by introducing students to career possibilities in the field of science and technology and aspects related to technology and human society.

The intended learning outcomes of the sequence which were developed and revised during collaborative discussions, and which follow the National Core Curriculum (NCCBE, 2004), are that the students will in detail:

1. Understand the basics of science concepts, principles, and systems in the contexts of materials and their properties (appropriate to grade level):
   - Students can identify basic materials and know the terminology used in describing them;
   - Students understand the meaning of the basic materials science concepts and principles; a material has certain physical and chemical properties and materials are distinguished from each other based on their properties; materials are used for production of artefacts and materials are selected for the artefacts based on their properties;
   - Students understand basic microscopic models, which describe structure of matter, properties, and behaviour of matter, especially in the case of metals, paper, and plastics;
   - Students understand the ways of representing materials on different levels: macroscopic, microscopic, and sub-microscopic levels as well as on the symbolic level, and can relate to and shift from one level to another;
   - Students can explain basic systems or processes used for production of materials and artefacts.

2. Use basic science process skills appropriate to the context of materials science and grade level:
   - Students make observations, measurements, and experiments;
   - Students develop and use categories to classify observations as well as analyse and interpret data;
· Students use reference sources to obtain information (Internet, textbook, handbooks, etc.);
· Students make estimations and predictions based on observations and current knowledge.

3. Use integrated science process skills appropriate to grade level:
   · Students identify variables and describe relationships between them;
   · Students formulate questions and predictions based on existing knowledge and basic models and set aims to the inquiry tasks;
   · Students collect and record data;
   · Students analyse data and draw warranted inferences or explanations grounded on the basic models;
   · Students draw concept maps.

4. Increase motivation and interests:
   · Students maintain a sense of curiosity about natural phenomena;
   · Students maintain interest toward science studies and careers in science;
   · Students voluntarily read websites, books, and articles about material science;

5. Demonstrate awareness of the social, history, and social aspects of materials science:
   · Students understand that social and cultural forces have influenced the historical development of science and technology, especially from the point of view of materials, artefacts, and their properties;
   · Students understand how technological advances have influenced the progress of science and how science has influenced developments in technology;
   · Students recognise the personal relevance of science and technology in daily life;
   · Students respect the contributions of science and technology to the quality of human life;
   · Students recognise the interdependence of science, technology, and society;
   · Students recognise the possibility for studies and careers in science and technology.
6. Communicate effectively using science language and reasoning:
   · Students use the language and concepts of science as a means of thinking and communicating;
   · Students prepare written articles describing the findings of investigations and the reasoning which led to the conclusions;
   · Students report results of inquiry tasks honestly.

7. Understand the nature of science and technology:
   · Students understand that science is an inquiry process used by humans to construct knowledge based upon observable evidence;
   · Students understand that technology is a creative discovery process used by humans to design usable artefacts;
   · Students distinguish between science and technology;
   · Students recognise the vital need for creative thinking and imagination in designing and conducting scientific inquiry and technological processes.

The intended learning outcomes reflect the multifaceted aims of science education in general. More precisely, in this teaching sequence there are aims concerning scientific content, but also aims that concern affective aspects, scientific literacy, understanding the nature of science, and skills related to scientific processes and thinking.

The scientific content of the teaching sequence was carefully prepared in order to encourage teachers to adopt the sequence for their repertoire. The teaching sequence supports students’ learning about the nature of materials science and technology, as students become familiar with how new innovations are refined into products in authentic environments through technological processes. Students also familiarise themselves with the methods of materials science by learning how research and development concerning materials science issues is performed with modelling and simulations that use high-technology devices. Moreover, students learn new materials science content, materials science terminology, physical and chemical properties, and the production and use of materials. They get acquainted with how the behaviour of materials can be explained by analysing their structures, and how microscopic models describe the properties and behaviour of materials. The structure of matter is one of the most fundamental topics in science, and a meaningful understanding of this topic is essential for developing a solid basis for further science studies; therefore, students take a close look at models that describe the structure, properties, and behaviour of materials. In detail, the significant scientific concepts and phenomena examined within the teaching sequence are raw material, material, substance, phase, physical properties,
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chemical properties, particle, monomer, thermoplastic polymer, thermosetting plastic, etc. The processes students become acquainted with are manufacturing iron from iron ore, manufacturing paper from trees and the manufacturing of different plastic qualities from crude oil. Finally, students learn about careers in material science and technology during the site visits, because they meet scientists, engineers, and other professionals found in modern materials science enterprises and laboratories. These encounters help them to see their career options from a new perspective.

The inquiry activities were conducted through employing the POE strategy (White & Gunstone, 1992). A POE activity includes three phases. In the prediction phase, Students are presented a particular setup of equipment with a worksheet and told them what they are expected to do. Students then make predictions about what will happen and add a brief explanation of why they think that will be the correct outcome. It is not fair to ask students to make predictions if they do not have any conceptual models or representations of the phenomena. Therefore, before the prediction phase, the phenomena should be discussed with the students to help them to recognise their representations. The students should become familiar with teaching models described in figures that outline behaviour of metals, plastics, and paper. Moreover, classification exercises can help students to recognise their existing models based on their experiences. The models could be introduced to students by a story. The students could be told that some researchers have suggested that these three models explain the behaviour of paper, plastics, and metal. Then the students are asked to investigate if the models explain the behaviour of materials in some inquiry activities.

In the observation phase, the activity is carried out, the phenomena are observed and results of observations and measurements are noted. In the final phase, explanation, the students attempt to deconstruct the observed phenomena and explain why things occurred in the way they did. The concept is that the teacher plays a minimal role in the POE, leaving students to do most of the discovery. Instead of acting as ‘The Leader’, the teacher can act as more of a master of ceremonies, letting the main attraction—the learning itself—be the main event. The predicted outcomes may have turned out to be correct.

After the cycles of designing and redesigning, the teaching sequence was finalised. The iterative process through which the pilot version was converted into the final one, and the decisions that were made during the process and their rationale based on the analysed data are described in more detail below. A detailed view of the teaching sequence with concrete instructions for all its phases is offered in the Student Book (Lavonen et al., 2009) and the Teacher Guide (Loukomies & al., 2009). The Materials around Us teaching sequence aims to help students become familiar with everyday materials like metals,
plastics, and paper both in everyday contexts and in their production or commercial uses. The properties and behaviour of common materials, the use of these materials, microscopic models describing the properties and behaviour of materials, and moreover, usage of (raw) materials in constructing and in manufacturing products, are introduced to students. In Photos 1, 2, 3, and 4, examples of the contents of the student book and a related page of the teacher guide are presented.
Photo 1. The Student Book helps students in distinguishing concepts like raw material and product.
Photo 2. An example of a student’s POE worksheet.
Photo 3. Example of an answer and explanation sheet in the *Teacher Guide.*
In order to facilitate the construction of a holistic view of materials, modern technology, and careers in related fields, different kinds of learning activities are used, and the topic has been approached from the perspectives of different school subjects. In more detail, career counselling, learning activities
typical of science learning, and learning activities typical of language arts are combined in the teaching sequence, so that this approach provides a possibility for teachers of different school subjects to work together. The teaching sequence offers a detailed description of a possible way of implementing industry site visits in science teaching and identifies the aspects that demand careful consideration in order to conduct the site visit procedure successfully.

The structure of the final version is presented below. Instead of the seven phases of the pilot version, there are three main stages in the final version: preparation, site visit, and follow-up activities. The major change from the pilot version is that all the tasks are more structured and the whole is more tightly organised, and the responsibilities of the participants are made explicit. The teacher is given more detailed information about how to proceed in certain phases. However, the structure is flexible enough to be implemented with a variety of companies and contexts.

To sum up the scientific content of the teaching sequence, in the preparation phase students get acquainted with materials paper, metal and plastic, the properties and behaviour of these materials, and the microscopic models that explain the behaviour. Students deepen their understanding of the topic through inquiry tasks that are related to the properties of the materials. During the site visit, students consider the properties and behaviour of the materials from the different perspective of production. They get information about how specific properties of certain materials are exploited, familiarise themselves with the economic and environmental aspects of manufacturing products, and discover career options within the field. Once back at school, students combine what they have learnt in the preparation phase and during the visit in a reporting task.

Table 6. Structure of the final version of the site visit teaching sequence.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Student activity</th>
<th>Teacher’s task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Planning and preparation</td>
<td>Classification tasks that guide students into the world of materials.</td>
<td>Introducing the inquiry tasks and working methods. Guiding the activities</td>
</tr>
<tr>
<td></td>
<td>Six optional inquiry tasks about the properties and use of materials and models that describe the structure of the materials (paper products, plastics, and metals).</td>
<td>but letting the students organise their working. Planning the organisation</td>
</tr>
<tr>
<td></td>
<td>Searching for information on the Internet about the company and finding out about its production processes.</td>
<td>of the visit with the company contact person and career counsellor.</td>
</tr>
<tr>
<td></td>
<td>Determining the perspective of the article (follow-up reporting activity). Examples include:</td>
<td>Planning the writing task in collaboration with the language arts teacher, who</td>
</tr>
<tr>
<td></td>
<td>-Materials used in the company’s production;</td>
<td>teacher teaches the article as a text type and intro-</td>
</tr>
<tr>
<td></td>
<td>-Raw materials and their origins;</td>
<td></td>
</tr>
</tbody>
</table>
2. The site visit

Students in a role: investigative journalist.
Introduction to the activities of the company, presentation:
- Manufacturing processes;
- Economic aspects;
- Environmental aspects;
- Careers and occupations;
Interactive sightseeing tour, students in small groups.
Data collection for the articles by conducting short interviews; Interviewing the personnel members, in small groups.
During the site visit, the students take notes about what they see and hear.

3. Follow-up activities

Collaborative article writing.
Concept mapping task for organising the new information.
Evaluation discussions and evaluation questionnaires (see the Student Book).
Feedback is sent to the contact person of the company.

Guiding the writing process, offering feedback and suggestions.
Organising the article’s publication.
- Collecting students’ opinions.
- Sending feedback to the company.

9.3 Data collection and analysis methods

During this DBR project, a site visit teaching sequence was designed, and a pilot test, two different cycles of design, implementation and refinement, and a final trial were conducted. After each cycle of implementing the designed teaching sequence, several sets of data were collected. The data collection is described in detail in Chapter 8. The data were analysed within the project before moving to the next cycle. In addition, the data was also analysed retrospectively, once the entire project was completed. The conclusions, which emerged from the analysis of the data and evaluations of the process, guided decisions about redesigning elements of the process.

For the scope of this chapter, the most significant data are those from the external evaluators’, students’, and teachers’ statements that refer to problematic, irrelevant, or incoherent aspects of the site visit teaching sequence and suggestions for amendments and improvements. The external evaluators’
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statements were collected into a document that was considered at the teacher-researcher meetings, where problematic aspects were discussed one at a time, keeping the relevant literature in mind, until new procedures were generated. The memoranda of the meetings, which took place within different cycles, are collected in the research log.

Data from the ESIAQ were analysed by comparing, with t-tests, the means of students’ answers before and after the site visit teaching sequence. Students were categorised on the grounds of their SDT-based motivation orientations by K-means cluster analyses of the AMQ, and representatives of each category (amotivation, controlled motivation, and autonomous motivation) were then chosen for semi-structured interviews. The clustering is described in detail in Chapter 8.

9.4 Implementations of the site visit teaching sequence

The design process of the site visit teaching sequence started with designing and testing the pilot version. The pilot version was then revised and the improved versions were implemented in two cycles. The implementations took place in authentic school contexts, and were led by science teachers and scaffolded by the researcher team. Teachers organised site visits according to the principles of the teaching sequence, with more scaffolding from the researcher team in cycles 1 and 2, and more independence in the final cycle. Even though there were a variety of companies that the students visited, all visits took place in materials science contexts, and the same materials science-related inquiry activities were employed in all implementations, and furthermore, compared with ordinary site visits, emphasis was on the preparation-visit-elaboration structure and instructional methods that supported students’ motivation and interest. In cycles 1 and 2, all refinements had not yet taken place yet, but the design was somehow unripe and yet to be improved.

9.4.1 Pilot Cycle: Okmetic Plc.

In order to test and further design iteratively the prototype of the site visit teaching sequence, a pilot cycle of the design (a site visit to the materials science industry plant Okmetic Plc) was organised in collaboration with a teacher, career counsellor, and company personnel in the spring semester of 2007. Okmetic produces silicon wafers for various technological purposes. 9th-grade students (N=21) from a suburban comprehensive school (Northern Helsinki, Finland) participated in the visit. During the pilot cycle, the prototype of the teaching sequence was tested. In the pilot cycle, the emphasis and
was on awakening students’ interest in and enhancing their motivation for science learning. The excursion was recorded on video and feedback from the students was obtained by use of a very basic form of a questionnaire. Students answered the questionnaire during their first science lesson after the visit. The feedback questionnaire consisted of five questions on a five-point Likert scale (1=‘very little’, 5=‘very much’) and one open-ended question: ‘What were you most interested in during the site visit?’. Means and standard deviations of the Likert questionnaire responses are presented in Table 7. Seven categories were inductively formulated from the students’ answers to the open question; those categories are presented in Table 8.

Table 7. Students’ evaluations of the site visit.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I learnt science during the visit</td>
<td>2.84</td>
<td>0.96</td>
</tr>
<tr>
<td>(Very little ...Very much)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I learnt about working life and occupations</td>
<td>3.32</td>
<td>0.89</td>
</tr>
<tr>
<td>(Very little ...Very much)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I learnt how science is applied in practice</td>
<td>3.47</td>
<td>1.17</td>
</tr>
<tr>
<td>(Very little ...Very much)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I’d like to have more site visits</td>
<td>4.16</td>
<td>1.12</td>
</tr>
<tr>
<td>(Very little ...Very much)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The site visit was</td>
<td>2.74</td>
<td>1.10</td>
</tr>
<tr>
<td>(Very uninteresting ...Very interesting)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Students’ responses to the open question ‘What were you most interested in during the visit?’. Examples of students’ answers re printed in italics.

<table>
<thead>
<tr>
<th>Applications of science</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-to see how silicon crystals are grown</td>
<td></td>
</tr>
<tr>
<td>-to see where science is used in practice</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The observed manufacturing processes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-to see how silicon wafers are made</td>
<td></td>
</tr>
<tr>
<td>-to see the machine tools</td>
<td></td>
</tr>
<tr>
<td>-to see the chemical storage</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The use of products of the industry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-to learn where silicon wafers are used</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meeting experts at work</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-to meet the professionals</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The environmental aspects</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-to learn how unthinking and egocentric we are</td>
<td></td>
</tr>
</tbody>
</table>
Coffee break
- food and coffee
- the coffee break was an extraordinary experience

General positive aspects
- we learnt so much
- nice to learn something new

Overall, students felt positively about the site visit. In their opinion, they learnt most about the applications of science, not so much pure science. Some aspects arose from the experiences of the pilot cycle that guided the design refinement. Firstly, it was clear that specific aims for the visit were needed. Students’ existing skills and knowledge should be communicated to the key company personnel, in order to help them organise the most suitable visit experience. Students’ planning and reporting tasks should be done with more care. The discussion also included the idea that some materials for advising teachers in organising site visits should be produced.

9.4.2 First Cycle: Vaisala Plc.

In the first cycle of the design process, 8th-grade students (N=14) from a suburban comprehensive school (Eastern Helsinki, Finland) visited the company Vaisala Plc, that has a reputation as a global leaders in environmental and industrial measurement, providing observation and measurement products and services for meteorology, weather-critical operations, and controlled environments.

The design process started with a planning meeting which the researcher team, the science teacher, and the career counsellor attended. It seemed that in the pilot cycle, students had had difficulties in finding the connection between their science studies and the visit (Argument ‘I learnt science during the visit’, Mean 2.84, S.D. 0.96), and as an outcome of the reflective discussions about the experiences of the visit, it was decided to include materials science-related contents in the preparing phase. Students conducted experimental tasks related to the physical and chemical properties of materials. One example was covering coins with another metal, in which a ‘copper’ coin was plated with zinc in a solution of sodium zincate and then appeared silver in colour. Then the plated coin was held in a flame for a few seconds and the zinc and copper formed an alloy of brass, which gave the coin a golden colour. The task instruction was structured by the teacher.

The intention was to familiarise the students with the professions and products of Vaisala Plc in order to enable them to see science, technology, and different materials applied in an authentic context. The students prepared
themselves by examining the company’s website and by drawing up interview questions. In order to enhance students’ responsibility for their own learning they were told that their output was to be a report about a certain aspect of the visit, written in pairs or small groups.

During the visit, students were shown a presentation and an exhibition about the company and its products, and how different materials were used in making them. At the end of the visit students released a radiosonde in the yard and followed it on a computer screen. During the visit, the students took notes about what they saw and heard. They also interviewed people who had relevant information for their reports. After the visit, the students completed their texts and the teacher compiled them into a booklet. There were no specific requirements for the style and structure of the reports.

Photo 5. Students sending a weather balloon aloft with the assistance of the company personnel in the yard of the company Vaisala Plc.

Compared to the pilot cycle, different occupations in the field of science and technology, especially in materials science, were emphasised in more detail. The scientific content of the site visit sequence was also strengthened.
9.4.3 Second Cycle: Metso Automation Plc.

In the second cycle of the design process, 9th-grade students (N=15) from a suburban comprehensive school (Eastern Helsinki, Finland) visited the company Metso Automation Plc. Metso is a global supplier of technology and services for the mining, construction, power generation, oil and gas, recycling, and pulp and paper industries. The second cycle of designing and testing the site visit teaching sequence started with a planning meeting that the researcher team, science teacher, language arts teacher, and career counsellor attended. The structure of the teaching sequence was revised from the seven-phase model of the pilot cycle to a three-phase model that consisted of preparation, visit and follow-up activities. This way the structure was clearer. A combination of materials science contents was included in the preparation phase of the second cycle, in the form of inquiry activities. Plastic, paper, and metal were chosen as the materials for students to examine.

It was determined that this time the students’ output would be an article related to the visit. Special emphasis was to be put on the writing process and studying articles as a type of text. This aim generated a natural means of integrating the science and language curricula. Before the visit, the students familiarised themselves with the company’s website, decided on the viewpoint of their articles, drew up questions they would ask employees, and conducted inquiry tasks related to paper, plastic, and metal.

The aim of the visit was to familiarise the students with science- and technology-related professions and show them how the materials they had examined within the inquiry activities were applied in an industrial context. With the help of the language arts teacher, the students wrote articles collaboratively about certain aspects of the visit. Unlike the previous cycle, the instructions for the article task were planned in collaboration with the Finnish teacher, who also took responsibility for introducing the students to articles as a text type and allocated language lessons to guide the students’ writing processes. The students’ questions were also prepared with the writing task in mind. In brief, the post-visit writing task was far more organised and featured more direct instruction than the previous cycle.

During the visit, the students were shown a presentation about the company and its products, and how different materials were used in the products. The students made notes about what they saw and heard. They also interviewed people who were experts on the topics of their articles. The teacher guide and the student book Materials around Us were prepared based on the experiences gathered over two cycles.
Photos 6 and 7. Students in a role of a journalist in the company Metso Automation Plc., asking questions of experts whose field of expertise is relevant from the point of view of the topic students had chosen for their articles.

In this cycle, the motivational aims were explicated in terms of instructional decisions. Additionally, the connection between the scientific content of the
visit was clarified and better connected to what is studied at school. The whole teaching sequence was revised to be more consistent and motivation supporting.

9.4.4 Final Trial

After finalising the student and teacher materials, the package was introduced to six lower-secondary school science teachers from the environs of Helsinki, Finland. The teachers participated in a two-day professional development course, in which they were introduced to different approaches to everyday materials and given ideas for how these materials could be taught to the students. There were a total of 110 students in the participating teachers’ classes. Teachers familiarised themselves with the site visit teaching sequence, and researchers and teachers then came to a shared understanding of its essential aspects, especially the means of enhancing motivation and interest, inquiry-based science teaching, and organising industry site visits. The teachers tried the inquiry tasks included in the procedure themselves, and they had time to plan their own site visits. In addition, the teachers and researchers collaboratively planned implementations of the teaching sequence for each teacher, because the teachers were scheduled to visit different companies. The meetings were collaborative and emphasised dialogue between researchers and teachers. After the course, the teachers organised site visits and related activities independently, without strict guidance from the researcher team. A reflective meeting was organised six weeks after the course. At this meeting, teachers were interviewed about their experiences of using a site visit teaching sequence as a way of teaching science. The interview was a structured reflective group discussion around the same themes as the student interviews. Because the researchers did not attend the site visits, the group interview was a vital means of gathering information about the final cycle implementations. The main aim of the final trial was to launch the design and see its potential in a real-world context.

9.5 Results

In this section, the results of the data analysis are discussed insofar as they offer information about applying the motivation and interest research and have had an influence on design decisions. The results concerning individual students’ learning, motivation, and interest are discussed elsewhere. Section 8.5.5 discussed in detail how the results influenced and redirected the design process.
9.5.1 Results of teacher interviews

In this section the results of the teachers’ interviews from cycles 1 and 2 and the final trial are considered with an eye to examining what motivational aspects of the teaching sequence arose from the interviews. The direct quotations of the teachers’ utterances have been chosen because they best convey the teachers’ experiences. The following aspects most commonly emerged from the teachers’ interviews: Firstly teachers found that the students’ feelings of autonomy were supported in the preparing phase (inventing questions and getting familiar with the company’s web site), when organizing the groups, and in the phase during which inquiry tasks were conducted. The students engaged in the inquiry tasks and worked intensively, they worked autonomously with ease, and the teachers felt that was due to the feelings of autonomy and freedom that engaged the students in the task. As some interviewed teachers put it:

...the inquiry tasks were done more independently, and that might have been the reason why they liked them...; ...it was just that they weren’t too guided and students got to proceed independently...; and ...it might have been that in the visit the questioning occasion was a full autonomy

In some cases the teacher organised the groups and the tasks to make there was something to do for all the group members in all the groups. In other cases the teacher let the students determine the groups and the work schedule:

...they mainly got to decide themselves about what kind of groups they were about to proceed...

All the interviewed teachers supported their students’ feelings of social relatedness by encouraging them to work in groups:

...then in the writing phase they benefitted from each other..., ...they did the tasks in small groups independently...

Teachers also found there were aspects in the procedure that supported students’ feelings of competence. The inquiry tasks were at an appropriate level for the students, which promoted those feelings:

...they were nicer than usual inquiry tasks as they were given independence and the tasks weren’t too difficult...; ... it was very well at students’ level and they got interested...

The fact that the students’ articles were to be published made the students think they needed to complete them with care. The teachers emphasised the significance of preparing the students well. Students’ pre-existing knowledge
and their opportunity to discuss with adults working at the site appeared to support their motivation and interest in the site visit:

...they also liked doing the pre-work and then when there was the mother-tongue and literature teacher involved brought something like how important it was that when the report was about to be written it had to be done properly when the mother tongue and literature teacher also read it...; ...it was valuable for them that they were treated [on the site] like real people...

The interviewed teachers mentioned aspects that concerned both the feelings and values of the students. They noted that it was important that the representatives of the company spoke about issues and phenomena that caught the students’ interest. The students were particularly attentive when the employees of the companies spoke about their own jobs and what they involved. The site visit also gave the students a perspective about what technology-related occupations are like and what career possibilities there are in this field. The possibility to have refreshments enhanced positive feelings towards the visit. Teachers noted:

...the most important thing influencing enjoyment was the refreshments but I think the most important was that it is not the career counsellor or me who is speaking about the issues and professions but someone that really does the work...; ...that they got to send the weather balloons themselves and then really saw what the function of the balloon was and what kind of preparation was needed, it was really interesting, and the students’ enthusiasm was the most important thing I remember...; ...the person who was speaking to the students was very interesting, and he had had the ability to speak so that he took the students’ worlds into account...; ...a student of this age gets interested if he gets where things really happen...

Even those students who were somewhat predisposed to dislike the exercise seemed to have enjoyed the visit. The students liked the environment, meeting people who worked in the field, hands-on tasks, and the interesting exhibitions they saw. The teachers interviewed also note some aspects regarding the practical arrangements of the visit. They found the site visit teaching sequence a natural way for interdisciplinary collaboration with their colleagues, from which all participants could benefit in their own ways. On the other hand, they considered the teaching sequence quite time-consuming; they experienced difficulties including it in their schedules and organising the practical issues with their colleagues. These issues may prevent teachers from organising other similar projects. In the first cycle, the teacher involved felt that she had to do the quite challenging organising entirely on her own.
9.5.2 Results of the ESIAQ

The results of the ESIAQ from cycles 1 and 2 are presented in Table 9. The questions are categorised into subscales based on SDT. Mean values (M1 and M2), and standard deviations (S.D1 and S.D2) before and after the implementation are presented for each category. The construction of the sum variables is explained in Chapter 8.1. In the far right column of the table is the result for the t-test that shows no statistically significant difference in any of the categories. The reasons for this are considered in the Discussion.

Table 9. Means, standard deviations, and t-values for motivation subscales based on students’ evaluations in first and second cycles.

<table>
<thead>
<tr>
<th>Design cycle</th>
<th>Motivational features of science activities in general and designed sequence activities</th>
<th>Science activities in general</th>
<th>Activities of the designed sequence</th>
<th>N</th>
<th>M1</th>
<th>SD1</th>
<th>M2</th>
<th>SD2</th>
<th>M2-M1</th>
<th>t*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Perceived autonomy/choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Perceived competence</td>
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<td></td>
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<tr>
<td></td>
<td>Support for relatedness</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Interest/enjoyment</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>Interest/value or usefulness</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>2nd</td>
<td>Perceived autonomy/choice</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Perceived competence</td>
<td></td>
<td></td>
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<td></td>
<td>Support for relatedness</td>
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<tr>
<td></td>
<td>Interest/enjoyment</td>
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<tr>
<td></td>
<td>Interest/value or usefulness</td>
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Examples of activities in each subscale:
1. I do the activity because I want to do it.
2. I think I am pretty good at the activity.
3. I feel close to my peers during the activity.
4. I enjoy the activity very much.
5. I think doing the activity could help me to learn science.

9.5.3 Results of student interviews

The self-determination theory of motivation categorises different motivation orientations. This categorisation was applied by employing the AMQ questionnaire and a cluster analysis of it, and grouped the students into three motivational categories based on the questionnaire data. Representatives from all the motivation orientation categories were interviewed. The interviews were analysed one cycle at a time. The aspects of the design that met the students’ needs and that arose from the students’ interviews in both cycles are explicated in Table 10. They were considered remarkable when refining the teaching sequence, and therefore they were emphasised in the final version.
Table 10. Motivational aspects that arose from the students’ interviews in both cycles.

<table>
<thead>
<tr>
<th>Amotivated students</th>
<th>Students with controlled motivation</th>
<th>Students with autonomous motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Significance of group work</td>
<td>-Breaking everyday routines</td>
<td>-Learning during the visit</td>
</tr>
<tr>
<td>-Significance of an authentic context</td>
<td>-An alternative way of studying</td>
<td>-Possibilities to choose</td>
</tr>
<tr>
<td>-Real-life applications of science</td>
<td>-Company of classmates</td>
<td>-Meeting people behind science careers</td>
</tr>
<tr>
<td></td>
<td>-Interesting content and context</td>
<td>-Group work, common aims</td>
</tr>
</tbody>
</table>

The significance of working in groups and meeting the authentic context and real-life applications of science arose from the answers of the amotivated students. One student said:

...well because when all the people have like different opinions about issues of what they prefer, and then when you combine them then it will be one big surprise box or such a thing from which you get all kinds of bursts of motivation and so on ...; ...especially that of course there are like friends and familiar people, so that made it easier, but also that when you study it kind of felt more effective because you had a good group so you also shared the aims and so on...

Students with controlled motivation noted among other things the possibility of breaking everyday routines, the significance of the company of their classmates, and a stimulating new context for studying. Finally, students with autonomous motivation mentioned the possibilities to learn new things during the visit, meeting real people working in the field of science and technology, and the possibilities to choose a group and work within it. One student described this experience as follows:

...well in principle when you had the kind of feeling that the tasks weren’t just put in front of you and you just have to do them, but that you had the possibility to influence what you are about to do so that...

In general, students, regardless of their motivation orientation, emphasised the significance of collaborating with peers and the authentic context, as the following two examples illustrate:

...well mm when you got there so I did realise that yes like this is quite nice probably to study if there are this kind of issues related to it..., ...before this [the visit]...for me it was important only to have paper in the store so that I could draw and so on but then when you start to think about the fact that there are so many phases when they do things, so of course it is interesting how they manage and how it is done, what are the processes ...
9.5.4 External evaluators comments

In the first cycle, external evaluators, professors in the field of science education employed by the project, wrote a report about their reflections on the site visit. They criticised the missing link between the classroom chemistry lessons and especially the concepts taught in them and the site visit. The external experts argued that the site visit was a detached factor appealing only to the affective domain of students’ interest towards science, and not connected with the actual study of science. They were also critical of the teacher being left alone, without support from the researcher team.

9.5.5 Re-design decisions

In this section, the design process is reflected upon, one cycle at a time. Problematic aspects that emerged from the reflective teacher-researcher discussions, student and teacher interviews and external experts’ comments are explicated. There is a table at the end of the description for each cycle, summing up the major problematic aspects and decisions about changing the weaknesses and inconsistencies in the procedure.

After the pilot cycle, the students felt very positive about the site visit in general and were willing to take part in other similar visits. They reported that they had learnt about how science can be applied in a real-life setting, and what kinds of occupations and careers there are in the field of science and technology. However, they did not learn as much about pure physics and chemistry during the visit, in their own opinions, so making the connection between the visit and the curricular aims more visible was an issue to be corrected. It was decided in the teacher-researcher meeting that some materials science-related inquiry tasks should be added to the preparation phase, which would help the students see the science content during the visit and encounter materials and their properties in a variety of contexts. Furthermore, company personnel should be properly informed about the degree of students’ existing knowledge in order to be able to speak at an appropriate level for the students. The students were not very interested in the reporting task in the pilot cycle. It was determined that clear instructions should be given for writing the reports and that students’ reports would be published on the school’s website, that they would evolve from being reports to being articles.
In the first cycle, the students were interested in studying in an authentic context. In the interviews they mentioned having been excited about the appealing role models, seeing how physics and chemistry were applied and the equipment they saw during the visit. The students also enjoyed working in groups. However, despite inquiry activities being conducted beforehand, the external evaluators were critical about there being too few links between the visit and studying science in the classroom. Moreover, in the teacher’s opinion, the co-operation between her and the researchers was incoherent, and the teacher did not get all the support she needed.

After this evaluation, the problem of connecting the visit to the curriculum was once again taken under consideration. More science content materials were included in the procedure, in the form of inquiry activities that also support the students’ feelings of autonomy and peer collaboration. Students’ autonomy was supported by generating such task instructions that the students could follow without direct guidance from the teacher. The students were given the opportunity to choose between various options, for example allocating the tasks to groups. Students’ collaboration and social relatedness were supported by letting them work in groups. All group members were needed in order to succeed with the experiment, and the students were encouraged to reach the explanations for the experiments in collaborative discussions. The researchers and the teacher who participated in the second cycle designed the inquiry instructions collaboratively.

Table 11. Problematic aspects and decisions associated with changes in the pilot cycle.

<table>
<thead>
<tr>
<th>Pilot Cycle</th>
<th>Problematic aspects</th>
<th>Data source</th>
<th>Decision about Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>-Lack of science content</td>
<td>-Students’ evaluation sheets</td>
<td>-Examining pre-existing knowledge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Inquiry tasks to introduce the content to students</td>
</tr>
<tr>
<td></td>
<td>-Lack of motivation in the reporting task</td>
<td>-Students’ evaluation sheets</td>
<td>-Structured reporting, the publishing of reports</td>
</tr>
<tr>
<td></td>
<td>-Overly-complicated science content in the visit</td>
<td>-Students’ evaluation sheets</td>
<td>-Clarifying discussions with the contact person of the company</td>
</tr>
</tbody>
</table>
Teacher-researcher collaboration and the expertise of a language arts teacher were employed when designing instructions for the reporting phase. It was decided that students should work as investigative journalists during the visit, so they could decide autonomously on the scope of their article according to their own interests and collect authentic data from an actual environment to be processed further into an article. The language arts teacher helped to generate structured and process-oriented instructions for the article-writing task. In the instruction, the emphasis was on the process of gathering and elaborating on the data collaboratively, and then on refining the articles. The role of the career counsellor was emphasised in the teacher-researcher meetings. It was determined that more time should be allocated for the students’ web-based preparation phase within the career counselling lessons, in order to help students form some sense of the company before the visit. The students prepared questions for the company’s personnel, and these were sent to the company before the visit, which also helped the company’s personnel to respond to the students’ particular interests.

Table 12. Problematic aspects and decisions about changes in the first cycle.

<table>
<thead>
<tr>
<th>First Cycle 2008</th>
<th>Problematic aspects</th>
<th>Data source</th>
<th>Decision about Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Teacher felt she was left alone</td>
<td>-Teacher’s interview</td>
<td>-More collaboration between the teacher and the researchers</td>
<td></td>
</tr>
<tr>
<td>-Missing link between visit and classroom studying</td>
<td>-External experts’ observations</td>
<td>-Formulating structured inquiry tasks -preparing worksheets for the inquiry tasks</td>
<td></td>
</tr>
<tr>
<td>-Stereotypical view of industry professions before the visit</td>
<td>-Students’ interviews</td>
<td>-Emphasis on the role of career counsellor in preparing students to figure out about careers in science and technology companies</td>
<td></td>
</tr>
<tr>
<td>-Unclear instructions for the reporting task</td>
<td>-Teacher’s reflections</td>
<td>-Structuring the writing task, defining the aims and instruction</td>
<td></td>
</tr>
</tbody>
</table>
The second cycle was already a reasonably well-functioning entity. However, though the researcher team supported the teachers in all the phases, there were still some issues with the inquiry work sheets. They guided the teacher to emphasise the correct answers rather than emphasising the inquiry process itself. The inquiry sheets were modified to support the phases of the process and new instructional pictures drawn by a graphic artist were added. The language arts teacher wrote explicit instructions for article writing and guidelines for evaluating students’ articles. These documents were included in the Teacher Guide.

In the final version, there are five different inquiry tasks in the procedure:
- In the dropping test, students drop marble balls on sheets of different materials and examine the point of impact;
- In the electrical conductivity test, students construct electric circuits and use objects made from different materials as components of the circuit, and then examine conductivity with a light bulb;
- In the ripping test, students rip sheets of different materials and examine the appearance of the traces made;
- In the heat conductivity test, students stand sticks of different materials in a container containing hot water, then attach dried peas with butter to the sticks and observe which peas drop off first;
- In the bending test, students bend thin sticks made of different materials and see what happens i.e., whether the sticks break or not and how they break.

After revisions made in the second cycle, the concrete design solutions, student book and teacher guide for the site visit teaching sequence Materials around Us, were finalised and published.

**Table 13.** Problematic aspects and decisions about changes in the second cycle.

<table>
<thead>
<tr>
<th>2nd Cycle 2008</th>
<th>Problematic aspects</th>
<th>Data source</th>
<th>Decision about Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-Unclear instructions in inquiry tasks</td>
<td>-Video recordings of students’ working</td>
<td>-Reconstructing the instruction sheets, adding informative pictures</td>
</tr>
<tr>
<td></td>
<td>-Indefinite reporting instructions in</td>
<td>-Researchers’ reflections to</td>
<td>-Explicit instructions for article writing</td>
</tr>
</tbody>
</table>
9.6 Discussion

There were two levels of aims within this research project. The first was to conduct a high-quality, iterative DBR project featuring an inquiry-based site visit teaching sequence with facets based on theories of motivation and interest and offering justifications for the decisions made within the project. The second-level aim was to employ the designed teaching sequence to enhancing students’ motivation for and interest and engagement in their science studies. The research questions and discussion represent these two perspectives.

The process of designing and redesigning is discussed from the perspective of the evaluation criteria of DBR introduced in Chapter 3. The focus of the iterative project was to design, in close collaboration with teachers, a materials science-related site visit teaching sequence that employed authentic industry site contexts and IBST principles, encompassed theory-based features intended to enhance motivation and interest, and enable interdisciplinary collaboration. The structured three-phase site visit model is a new innovation that enriches traditional field visit practice, and has a significant potential to be used and applied by science teachers. This meets the requirements of novelty, relevance, and generalizability of the results of a DBR project (Edelson, 2006). Furthermore, the project criteria of reflecting problematic aspects in an authentic educational context and seeking solutions in an iterative process were met. DBR appears to have been a suitable approach for developing the teaching sequence, especially because of its cyclic nature. Such a multifaceted structure would have been impossible to construct in one uninterrupted process. Many essential aspects were revealed only through testing the teaching sequence in an authentic school environment.

The pilot version of the site visit teaching sequence was based on the literature related to motivation and interest, but the guidelines for the teacher were too implicit. Alongside the iterative design project, various sets of data were collected during the process in order to meet the criterion of formative evaluation (Edelson, 2006). Besides, the teaching sequence was discussed
reflectively in informal teacher-researcher meetings. As a result, it became more structured and multifaceted. Many aspects of the teaching sequence were scrutinised and better practices were developed as shared activities with the teachers.

Based on the data, changes in the procedure were instituted. Some changes were made after informal reflective discussions between teachers and researchers. The connection between the site visit teaching sequence and the curricular content aims was a serious concern of the external evaluators. Kisiel (2005) shares this concern when arguing that connecting schoolwork and visits helps teachers to see the benefits of a visit from the point of view of implementing the curriculum. As a result, the connection was tightened with structured inquiry task sheets. The experiments can be used flexibly in the context of materials science. The collaboration between the teacher and the company contact person was also emphasised in the final version of the teacher guide, in order to inform the company of the content related aims of the students. Finally, the reporting task was restructured and the views of the language arts teacher were taken into account. It was revealed in the reflective discussions with the first cycle teacher that the reporting task was not engaging for all students. Students’ interest in inventing the questions for the visit was enhanced in the last cycle by telling them that the questions would be asked in an organised interview situation, in which they would encounter many experts from different fields related to the company, and the students would use the answers for their later writing task. The students were given the opportunity to choose who they wanted to interview.

It is likely that this autonomy-supporting authentic situation, which was not directly controlled by the teacher and an atmosphere in which the students were treated as adults encouraged them to invest in the task. This is in line with the IBST criteria suggested by Minner et al. (2010), as they argue that student responsibility is an essential feature of inquiry instruction. Autonomous regulation of behaviour, in turn, is related to better quality learning outcomes (Deci & Ryan, 2008). Linking the visit with the curriculum is in line with the arguments of Storksdieck (2001). He argues that a student preparation phase, examining the students’ prior knowledge and attitudes, and a follow-up phase are essential to connect the visit successfully to the curriculum. The follow-up phase turned out to be a fruitful possibility for integrating school subjects representing different teaching cultures, in detail science and language, in a way that the activities benefit the aims of both of these subjects. Drake & Burns (2004) define this kind of integration as interdisciplinary integration.

When considering the site visit teaching sequence from the point of view of students’ motivation and interest, the emphasis was on students’ inter-
views, because the ESIAQ did not reveal significant differences between students’ evaluations of the teaching sequence and ordinary science lessons. Almost all the values of M1 and M2 lie between 4 and 5 (on a scale of 1 to 7), indicating that students rated both ordinary science teaching and the teaching sequence rather positively, which is an encouraging aspect from the science education point of view, but somewhat discouraging as the teaching sequence was not experienced as significantly better. It may be that due to the relatively short duration of the intervention, its effect remained untrackable by statistical means, or that the concepts that were used in the questionnaire may have been imperfectly chosen, and as a result been difficult for the students to understand. Alternatively, possibly the second time of completing the questionnaire was not as interesting as the first time to the students and the results reflect merely the motivation to answer a questionnaire rather than motivation for studying science. The interviews offered more explicit information about the difference between ordinary science lessons and the teaching sequence.

Based on the interview data, the fact that the teaching sequence appealed to the full range of students irrespective of their motivation orientation is a productive starting point for future designs of interdisciplinary learning sequences in out-of-school settings. All the interviewed students evaluated the site visit teaching sequence positively and would not rather have wanted to skip the site visit and study at school in the normal way. Especially remarkable was that the amotivated students’ eyes seemed to have been opened after seeing the relevance of their science studies as they connected school science with science as applied in authentic settings. Also significant was the students’ appreciation of the possibilities to choose their tasks. Lavigne, Vallerand, and Miquelon (2007) argue that science teachers' support of student autonomy may have an impact on students' autonomous motivations towards science, and even on their pursuit of working in a science-related domain, which is after all the ultimate goal of such site visits.

The site visit teaching sequence brought together out-of-school learning and classroom study in a manner that the two ways of learning science benefited from each other. The students saw science applied in a real-life setting; according to Margel et al. (2008), encountering materials and their properties in different contexts and within different activities is also important from the learning of concepts perspective. The students prepared themselves at school, encountered the materials science content in an authentic context, and then further deepened and processed their understanding of it back at school. It is suggested that this is a reasonable way for using limited time resources, so that students learn in a manner that also makes knowledge transfer possible. Moreover, despite the skills related to traditional school subjects, students
also learn interdisciplinary skills introduced by Drake and Burns (2004), such as thinking and research skills.

The teaching sequence can be implemented by following the Student Book and the Teacher Guide, but an in-service course is recommended to discuss the operating mechanisms of the basic psychological needs and their influence on student motivation. Motivating students should not be seen as isolated factor of the lesson, but more as a philosophy that grounds all decisions concerning activities in science lessons.

In order to accomplish the reporting task successfully, students should be trained to use interviewing techniques and also about technological devices used for gathering data, though many students may well use their own mobile devices. The process-writing technique should be practised, and collaboration with the language arts teacher is highly recommended for this phase. When examining the careers in the field of science and technology, close collaboration between the science teacher and the career counsellor is recommended. It would be best if pairs or groups consisting of the science teacher, language arts teacher, and career counsellor can conduct the implementation in collaboration.

The inquiry activities connect the visit and the science content studied at school, and offer a context for students familiarising themselves with the properties of materials and the use of model-based reasoning. The organisation of the inquiry tasks is explicated more fully in the teacher guide. Consequently, the teacher should be familiar with the essential features of the teaching sequence, in order to implement it effectively, as companies may have a strong, pre-existing idea about what a site visit should be like, and what the students should be doing during such a visit. Negotiating the best possible solution, which follows the guidelines of the teaching sequence, is the teacher’s responsibility; this opens interesting possibilities for teachers’ in-service training.

Motivation in this research is considered in the light of SDT. Central to this theory is the argument that motivation may be enhanced by supporting the fulfilment of students’ basic psychological needs. Giving students the responsibilities introduced in the previous paragraphs supports their need for autonomy. All tasks were conducted in collaborative groups that supported students’ feeling of social relatedness. Feedback from the teacher and peers and the output (article) per se all had the potential to enhance students’ feeling of competence. Finally, students’ curiosity was piqued by studying in an interesting and authentic context.
10 Promoting students’ interest in and motivation for science learning: The role of personal needs and motivation orientations

Despite what is known about the reasons that enhance students’ interest towards an activity, educational systems are failing to direct students’ general interest towards science and in motivating students to follow science-related careers (Osborne, 2008). A European Commission report (EU, 2004) emphasises that school science should better represent real science practice and cater more effectively to the interests of young people. Furthermore, the OECD (2008) recommends that students should have access to realistic information about science and technology (S&T) careers through direct contacts with professionals. Tytler, Symington, and Smith (2010) share this view as they argue that partnerships between schools, communities, and industrial organisations are important for local level curriculum development if the aim is to have an impact on students’ interests. Based on their review of the literature concerning supports and barriers to science, technology, engineering and mathematics (STEM) engagement, Tytler, Osborne, Williams, Tytler, and Cripps (2008) argue that the primary focus for intervention should be at the primary and early secondary school levels.

Despite the efforts of science education researchers to establish novel, rich, fruitful, and stimulating science teaching and learning environments, only a few students have typically increased their interest in science learning within the projects (Osborne, 2008). Based on the self-determination theory of motivation (SDT, Ryan & Deci, 2002), it is assumed that students differ from each other in relation to their motivation orientations towards a certain topic. That is, they do not have similar prior expectations and emotions towards an activity, and therefore it is deemed more relevant to consider which aspects in a given teaching sequence appeal to certain students with particular motivation orientations rather than examining the motivation and interest development of a whole group. What causes the differences between students in their motivation and interest development is not directly within the scope of this study, but students’ prior learning experiences and assumptions about learning situations (Salonen, Lehtinen, & Olkinuora, 1998) and their former emotional experiences or emotions towards the activity (Jarvenoja & Jarvela, 2005) have been considered as possible factors for the individual differences in motivation and interest development. Given that differences in motivation
orientations exist, a deeper scrutiny was conducted about which aspects of a certain teaching intervention appeal to different students.

It is assumed that the maintenance of interest might occur if the students experienced the actual learning activities as being personally relevant or meaningful (Lewalter & Krapp, 2004), and if the site visit was carefully connected with the activities at school before and after the visit, through phases of planning, visiting, evaluating, and reporting. The novelty and authenticity of the context provide the students with complex and even surprising phenomena to observe. To ensure a digestible experience and support student engagement, the students prepare themselves carefully for the visit by searching for information about the company in advance. This combination of comprehensibility and novelty should enable situational interest to emerge (Silvia, 2008). Feelings of autonomy, social relatedness, and competence are emphasised by guiding the students to work as journalists, and prepare articles based on interviews they conduct in small groups during the site visit.

10.1 Research question of the second substudy

Students’ interest and motivation towards science learning was examined by designing and developing a theory-based teaching sequence enriched with activities that are believed to promote students’ interest in and motivation for science learning and science-related careers. The aim of this part of the research was to understand how individual differences related to motivation orientations and fulfilment of basic psychological needs based on SDT operate in that promotion. The research question of this part of the research is:

How did students with individual differences in their motivation orientations experience a teaching sequence enriched with motivation and interest promoting features?

The meaning of the concepts of interest and motivation, and the distinctions between various students’ motivation orientations are defined in Chapter 4. In this chapter, the introduced teaching sequence is considered from the perspective of the aspects that aim at promoting student engagement. Furthermore, the means of data collection and analysis are described, and the results of the data analysis are introduced. Finally, the findings about the benefits of the designed sequence for students’ engagement are discussed.

In order to answer the research question, a teaching sequence for science education (which is presented in detail in Chapter 7) was designed. The sequence takes students’ basic psychological needs into account in order to facilitate the arousal and development of their interest in and motivation for
science learning, and aims at promoting scientific understanding related to materials science. This undertaking should potentially provide evidence for understanding why the same teaching technique is more beneficial for the development of some students’ interest and motivation but not for others.

It was noted how this intervention affected students with qualitatively different prior metacognitive experiences (concerning the degree to which they experience science courses fulfilling their three basic psychological needs), and, furthermore, different motivation orientations. It is assumed that motivation orientations (namely amotivation, extrinsic-external, introjected, identified, and integrated-motivation and intrinsic motivation) generated as a result of the degree of fulfilment of the three psychological needs, characterise individuals entering the science class and their aspirations for science learning.

10.2 Data collection and analysis methods

Two separate groups of 8th- and 9th-graders (mean age 14.2 years) from Finland (altogether N=27) participated in the study. The groups came from two schools. Separate site visits were organised for the groups, because the groups participated in the research in different phases of the design process. However, the results from these two distinct cycles are considered to be comparable with each other, as the procedure of the site visit was similar in both cycles and the researchers were also present to ensure the similarity of the two implementations.

The site visits were constructed in a way to facilitate the fulfilment of the three basic psychological needs. In order to test whether the aspects intended to motivate and increase interest were emphasised within the implementations, two researchers analysed the motivation- and interest-promoting characteristics of the implementation from videotapes using content analysis, and categorised the features according to four categories: autonomy-supporting activities, support for students’ feeling of competency, support for students’ social relatedness, and support for student interest. These two researchers supplied a list of activities that could be directed to fulfil different psychological needs. The interrater agreement was very high, and after a discussion between the researchers, a consensus was reached. The designed sequence provides a sophisticated and rich learning environment that enables students to find activities that could fulfil their personal needs and therefore enhance their interest in science and science-related careers.

The data collection methods used in this substudy are described in detail in Chapter 8. Before the implementation of the sequence, all the participants were tested with the ESIAQ and AMQ questionnaires. In this phase the target
activity was their ordinary science lessons. Immediately after the implementation, the participants were tested with ESIAQ in order to recognise the motivational features of the implemented sequence. On the basis of the AMQ questionnaire data, students with different motivation aspirations were selected for an interview through K-means cluster analysis. A representative of each motivation aspiration group (the closest to the cluster centre) was interviewed following the protocol described in Chapter 8.

10.3 Results

10.3.1 Comparison of motivational and interest-related characteristics of science learning activities, in general and in the designed teaching sequence

For the purposes of this study, when analysing the results of the ESIAQ, the whole sample was analysed at once. The reason for this was the small amount number of students in each group. The two implementation cycles were considered similar enough, because the researchers controlled the implementation of the site visit sequence and activities before and after the visit. Furthermore, as the differences between schools are small and all school curricula are based on the NBCCE, ordinary science lessons can be expected to be alike regardless school. Sum variables for students were constructed based on the items for each of the five subscales of the ESIAQ for the ordinary science learning activities (M1) and for the designed teaching sequence (M2). The construction of the sum variables is explained in Chapter 8.1. The means and the standard deviations of the subscales are presented in Table 14. The students as groups were generally moderately positive (means > 4.5) for both the ordinary science activities in general and the designed teaching sequences. The paired-samples t-test between the motivational features of ordinary science learning activities and the designed teaching sequence (M2–M1) revealed no significant positive differences, though more thought-provoking aspects were revealed in the interviews with individual students. These results are presented in the next paragraphs.
Table 14. Means, standard deviations and t-test results for motivation subscales based on students’ evaluations of motivational features of science activities in general and designed teaching sequence.

<table>
<thead>
<tr>
<th>Country</th>
<th>Science learning activities in general</th>
<th>Designed teaching module</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motivational features of the science activities in general and designed teaching modules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>Perceived autonomy/choice1 4.61 1.15</td>
<td>4.22 1.10</td>
<td>-0.40 1.8</td>
</tr>
<tr>
<td></td>
<td>Perceived competence2 4.60 1.23</td>
<td>4.63 .79</td>
<td>0.03 0.2</td>
</tr>
<tr>
<td></td>
<td>Support for relatedness3 4.70 1.09</td>
<td>4.49 .86</td>
<td>-0.21 1.4</td>
</tr>
<tr>
<td></td>
<td>Interest/enjoyment4 4.44 1.25</td>
<td>4.31 1.00</td>
<td>-0.13 0.7</td>
</tr>
<tr>
<td></td>
<td>Interest/value or usefulness5 5.08 1.55</td>
<td>4.68 1.52</td>
<td>-0.40 1.9</td>
</tr>
</tbody>
</table>

*) ns \(p > 0.05\). Item examples in each subscale:
1I do the activity because I want to.
2I think I am pretty good at the activity.
3I feel close to my peers during the activity.
4I enjoy the activity very much.
5I think doing the activity could help me learn science.

10.3.2 Differences in the opinions about the motivating features of the designed teaching sequence among the students with different motivation orientations (SDT)

The amotivated participants

According to Ryan and Deci (2000), amotivation results from three reasons: not valuing the activity, not feeling competent to do it well, and not believing it will yield a desired outcome. In the interview, the amotivated participants perceived the sequence as being more interesting than ordinary teaching. The justifications indicate that the sequence met their personal needs. One of the amotivated students (FN_02) stressed that the designed teaching sequence was a valuable and interesting activity and she “learned a lot of interesting things”. For example, she said:
Before this Metso Automation (the company)…for me it was important only to have paper in the store so that I could draw and so on but then when you start to think about the fact that there are so many phases when they do things, so of course it is interesting how they manage and how it is done, what are the processes ...

A by-product of a low self-competence may be the isolation from the group of students who were highly motivated to do a particular activity. The sequence also gave the amotivated students a chance to be members of a group and fulfil their need for relatedness and self-competence. The same amotivated student (FN_02) enjoyed working with her classmates, and she felt that co-operation is a very valuable thing that enriches studying. She put it thus:

well because when all the people have like different opinions about issues of what they prefer, and then when you combine them then it will be one big surprise box or such a thing from which you get all kinds of bursts of motivation and so on ....

The other interviewed amotivated student (FN_07) emphasised the support of her classmates for her studies, and considered the conversations valuable for learning. She said:

with [name] we both figured when we explained to each other repeated after the trip that what remained in our memories or the teacher asked us first to think with the pair that what you remember and everything so then we chatted with [name] so we did both notice that we remembered and learnt something... and ... when both can divide opinions and then decide together when both may have different issues and questions and all and then it somehow goes in an easier way and we fulfil each other.

The authentic context was also important, as the same student (FN_07) stated:

well mm when you got there so I did realise that yes like this is quite nice probably to study if there are like this kind of issues related to it...

The amotivated students did not mention anything explicit related to their need for autonomy or self-determination. After the site visit sequence, the amotivated students had somehow developed the quality of their motivation showing cues of some satisfaction of competence and relatedness needs but still not experienced support for their need for autonomy.

The externally-regulated participants

Ryan and Deci (2000) define external regulation as the least autonomous form of extrinsic motivation, where behaviours are performed to satisfy external demands. In class settings the need for high grades is usually the external demand that regulates student behaviours. One of the externally-regulated
students (FN_06) did not experience any support for his feeling of competence or autonomy, and he still assigned this to the teachers. He said:

...well yes that I haven’t myself decided about anything that I have been told and then I have done it is as well if the teacher decides...

Both externally-regulated students remembered significant amounts of content- and context-related details of the site visit. For example, one (FN_06) mentioned the authentic context setting and the employees of the company, probably because he found their occupations interesting:

...well it was good when they told us quite a lot about what they actually do there and they explained well about their own experiences and where they came from...

Another (FN_11) referred to the opportunity to participate in the activity during the visit, stating:

sending the radiosondes aloft, at least we remember that because we did it ourselves.

This student also emphasised the significance of being related to the group, for example:

I don’t know, it was nice to leave the school with your friends early in the morning...it [completing the tasks during the visit] was nice because after all we are...we are best friends...well, the trip itself because we have such a good class spirit.

The significance of the science content was not emphasised by this interviewee. It remained unclear whether it would have made any difference if the trip had been for an entirely different purpose. The interviews of these two students do not paint a picture of especially critical students, but of students that are satisfied if the instruction is clear, there not too many decisions that must be made autonomously, and there are possibilities to spend time with friends.

**The participants with identified/intrinsic regulations**

Individuals who have identified with the personal importance of certain behaviour or a given activity are more autonomous and self-determined compared to individuals with other forms of extrinsic motivation (Ryan & Deci, 2000). Students with identified regulation emphasised the importance and value of the sequence for understanding the related science disciplines and filling the gap between theory and reality. One student with identified regulation (FN_09) stated:
I have somehow liked studying physics and chemistry so it has not like at least made worse, well somehow it increased interest ... well then from another point of view at the company when you chatted with those people it was just the action and how specific everything was...

Another student (FN_15) with identified regulation also found his motivation enhanced because of the possibility to participate in real-life work. He stated:

Also the first impression of the company, the refreshments and the atmosphere that created a feeling of participating a Nokia press conference with international guests, it increased my interest...

This student might have experienced his role in the visit a bit differently compared to an ordinary student’s role at school, enjoying the opportunity to be a part of some real-world business, and thus enhanced also his feeling of competence.

Additionally, the students with identified regulation stressed the value for enhancement of their personal relationships and fulfilment of their need for relatedness. One (FN_09) said:

especially that of course there are like friends and familiar people, so that made it easier, but also that when you study it kind of felt more effective because you had a good group so you also shared the aims and so on ...

This student also stressed the value of the sequence for fulfilment of their need for autonomy and its usefulness for enhancing their interest in science. He said:

...well in principle when you had the kind of feeling that the tasks weren’t just put in front of you and you just have to do them, but that you had the possibility to influence what you are about to do so that...

Another interviewee with identified regulation (FN_15) emphasised his need for autonomy in relation to his need of social relatedness. He said:

...well it was conducted in groups and there we had the possibility to decide who to work with...

So it was not only the relatedness but also the autonomous decision-making of choosing with whom to work. Even though the interviewees in this category scored high in the subscale that identifies regulation, the score in the extrinsic subscale was high with one interviewee. This student (FN_15) said:

it [motivation] changed into better direction because at first studying chemistry was not that important but as I visited a company in which I could easily see where you can get by studying chemistry, it increased the motivation.
This is in line with what can be seen in the subscale means of this student: even though he has identified with the values and aims presented by the teacher and in the curriculum, the influence of the external prods (for example, the possibility to later get a highly-valued job and the high salary that comes with it) is obvious in the opinions of this student.

### 10.4 Discussion

This study has helped us to contribute to the understanding about individual differences in interest and motivation development in the context of science learning. For this purpose, a teaching sequence for science education was designed with the aim to enable lower secondary school students develop their interest in and motivation for science learning, and examined the way this intervention affected students with different initial motivation orientations. The designed teaching sequence incorporated activities (i.e., a visit to an industrial site) that may have established situational interest in science that, if maintained long enough, might help students to see the value of the activities and thus be transformed into genuine personal interest (Schiefele, 1991; Krapp, 2002). In parallel, the designed teaching sequence incorporated activities that, according to self-determination theory (Ryan & Deci, 2000), might fulfil students’ innate psychological needs and furthermore support the development of the participants’ intrinsic motivation.

#### 10.4.1 The effect of designed teaching sequence on students’ perceived interest and motivation

Quantitative measures with the ESIAQ showed that, despite the efforts in designing and implementing an innovative teaching sequence with all the characteristics introduced above, there were no statistically significant differences between students’ perceived autonomy and choice, competence, support for relatedness, interest and enjoyment, and interest and value or usefulness before and after the site visit teaching sequence. Based on the statistical analysis of the ESIAQ, a null hypothesis cannot be rejected. There may be three explanations for this.

First, the short duration of the sequence may be the reason for not generating large enough difference in students’ motivation to track with the ESIAQ. Similar evidence that short-term interventions cannot generate permanent changes is reported in Lott’s study (2003). Laursen, Liston, Thiery, & Graf (2007), after reviewing several papers considering the effects of short-term interventions, argue that despite the popularity of the short-term intervention model, there is little convincing research literature about its statisti-
cally significant effectiveness (p. 50), and that short duration interventions cause mainly affective outcomes, as participants usually enjoy these occasions. Why did students then not perceive the expected enhancement of their interest and enjoyment? Finnish students have become used to this way of working, as it is recommended in the Finnish National Core Curriculum (NCCBE, 2004), and there has been a tradition for over twenty years of organizing site visits in Finland (Kuitunen & Meisalo, 1988). In any case, the question remains: what is a sufficiently long intervention to promote students’ interest and motivation?

Secondly, one could deduce that the lack of significant improvement can be interpreted partly as resulting from difficulties students had, despite the explications, in differentiating between ordinary teaching and the sequence, as the sequence was supposed to have a fixed connection with the curriculum. However, before the students started to complete the questionnaires this was stressed by the researchers and it became clear to all the participants. Still, it is obvious that the targeting of the questionnaire was somewhat unsuccessful. Some stimulation, for example videos of the visit, might have been helpful before the second round of questionnaires. The interviews, by contrast, did succeed in distinguishing the site visit sequence from ordinary teaching.

Thirdly, the results can be explained on the basis of the inappropriateness of the ESIAQ itself in grasping slight differences between the designed teaching sequence and ordinary teaching. For instance, a ceiling effect was observed in most subscales. Students with high scores (5–7) on the pre-visit questionnaire Likert scale could not place themselves much higher after the implementation, and thus a noticeable difference is visible only in the answers of students who had low scores in their pre-visit questionnaire (in this case the amotivated ones). However, as happens in most intervention studies (see Martin, 2008), the sample of the study was quite small and different motivation orientations were represented unequally. Amotivated students represented only a small portion of the whole sample (3/27). Alternatively, the initial ceiling effect might have occurred because the students were probably very motivated when answering the questionnaire the first time, as it felt special to be involved in an educational experiment. In contrast, after the intervention they were not so happy when they realised that the same procedure of filling the questionnaire was about to be conducted again. However, design-based research is also about methodological design, attempting to find the most suitable ways of gathering information about a certain phenomenon. Therefore multiple methods are used, accepting the risk that not all of them may grasp the relevant information.
10.4.2 Students with different motivation orientations

Beyond the methodological issues that arose from the ESIAQ, the analysis of the quantitative data revealed important evidence in support of motivational theories. Specifically, the subscale means of some representative participants appeared to be different from expectations. Although the amotivated students scored lower in both extrinsic and intrinsic motivation, being obvious representatives of the motivation orientation, it is notable that other participants had high mean scores in more than one subscale of extrinsic and/or intrinsic motivations (see the numbers in italics in Tables 1 and 2). Therefore, the border between clusters of different motivation orientations was not pronounced, and representatives of clusters even had characteristics of other types of regulations. This leads to the thorny question of whether extrinsic and intrinsic motivation orientations are dichotomous or continuous. Lee et al. (2010) argue that these two can coexist and should be dichotomised as two goals rather than examining them as lying on a continuum of a single motivational force, as the SDT proposes (see Ryan & Deci, 2000). Moreover, it is evident that differently-regulated orientations may coexist within the same individual, although only one is prominent. Therefore, the students were distinguished based on their prominent motivation orientations, understanding that this categorisation is context-bound and may vary between different situations.

Although hardly any statistically significant effects were found in the questionnaire data, some effects within the people became salient with during the interviews. The most important evidence from this project emerged from the qualitative data showing that students with different prominent motivation orientations (even with the limitation discussed above) found different aspects of the sequence appealing and important. These aspects are compatible with the characteristics that guide the behaviour of an individual with a given motivation orientation across situations and domains, as assumed by the SDT. For example, amotivated students were initially very critical towards studying science, did not feel themselves competent in this relation, and were very suspicious about whether studying science had any relevance to their lives. They did not seem to recognise the connection between science studies and their own future career possibilities. During the sequence, however, they found the activity in its authentic context to be valuable and very interesting, as they met the real people behind job descriptions, had the opportunity to speak with them, and saw how topics studied at school could be applied in a real setting. This outcome is in line with the results presented by Hulleman and Harackiewicz (2009), as they argue that encouraging students to make connections between science course material and their lives pro-
motivated both interest and performance for students with low-success expectancies. Moreover, these students noted that their competence and feelings of social relatedness had been successfully supported. On the other hand, they did not refer to the aspects that intended to enhance their need for autonomy. In other words, amotivated students were attracted by learning activities that fulfilled their basic needs for competence and relatedness to some extent, but not their need for autonomy. This was not surprising; as Shunk, Pintrich, and Meece (2007) stressed, amotivated students do not ascribe intention or self-determination to their actions. According to the SDT categorisation, amotivated students after the implementation acquired a controlled orientation (Deci & Ryan, 2008).

Externally-regulated students, in turn, experienced the sequence positively because it broke the everyday routine and saved them from their teacher’s strict supervision. Within ordinary teaching, while regulating their behaviour to external demands, they usually experience high levels of anxiety and fear of failure, emotions that threaten both their need for autonomy and their need for competence (Johnston & Finney, 2010, p. 293). These students found the supportive atmosphere of the group important and thus improved their competence and fulfilled their need for relatedness. Externally-regulated students did not experience much autonomy but on the other hand, did not long for it either. They also appreciated the possibility to meet real people in the field of science and have the opportunity to speak with them to learn what a career in the field of science and technology might actually involve.

The more self-determined students’ actions were before the implementation, the more they valued the designed teaching sequence, in respect to the autonomy they experienced and the value of the activity per se. Students with internalised regulations appreciated the autonomy offered to them and considered it essential for their motivation. Moreover, contrary to the ESIAQ results, the interviews revealed that the sequence also enhanced students’ value-related component of interest for those students with more internalised regulations. For instance, students with identified regulation appreciated the possibility to see the future value of their science studies, in other words what possible career choices they had. These students were happy to share their already existing interest towards the topic, and the tasks related to it with their group members. Before the site visit, these students had an autonomous orientation and experienced satisfaction for all the three basic psychological needs to some degree. After the implementation, these students cited elements of the sequence that promoted their affiliation, generativity, and their personal development (see also Deci & Ryan, 2008).

A rich educational environment was designed that generated situational interest, as expressed by students in the interviews. It has been argued that
subjective appraisals of novelty, complexity, and comprehensibility of an object or an event, may arouse students’ situational interest, and the authentic context (industry site) for studying was probably new for almost all the students, and it made visible complex and even surprising phenomena (Silvia, 2008). Moreover, the more the students had internalised the regulation of their actions with respect to studying science, the more interested they were in the topic already. They felt themselves competent and willing to learn, and the new things they learnt within the sequence were planted in fertile soil.

What really awoke their situational interest is a complex thing to evaluate, at least retrospectively. Palmer (2009) used within-action short questionnaires in order to track the aspects in the lesson that affected students’ situational interest. In the sequence, there were aspects that may have either generated new situational interest or actualised a latent personal interest. Retrospective interviews were used in order to examine what the interesting aspects in the sequence were, according to the students’ own experiences. It is understood that by choosing this option, it cannot be absolutely clear whether it is the interesting features of the situation that generated situational interest or the existing positive dispositions of students towards certain phenomena and topics that were actualised or awoken due to the intervention. However, even though the situational and personal aspects of students’ interest cannot be precisely tracked, it is important that students found something in the intervention interesting. This is especially significant for the amotivated ones, for whom offering something that awakens interest is critical.

The students’ statements, however, challenge the direct effect of situational interest in the development of personal interest. What the participants stressed is that they found aspects in the designed teaching sequence that fulfilled their psychological needs. They all mentioned aspects in the sequence that, according to the SDT, were compatible with their motivation orientations. The evidence extends knowledge in such a way that the three basic psychological needs are linked with interest development in classroom settings. Individual differences in interest development revealed after a set of learning activities are likely partly explained by the strength of the basic psychological needs students may have. Although the three basic psychological needs are supposed to be universal, the idea that these have a different strength and demand for satisfaction among individuals is perfectly reasonable. Prior metacognitive experiences form the individuals’ engagement in similar activities and create a subjective specific motivation orientation towards various activities and domains. Each motivation orientation results from a satisfaction at a different level of the three basic psychological needs. That is, each time individuals start a new activity they have a subjective estimation or bias for what psychological needs could be satisfied by the activity
and generate different aspirations for which of their needs the activity could satisfy. This bias makes individuals sensitive to some activities and not to others. This idea leads us to formulate the ‘personal needs’ mediation hypothesis; adolescents’ psychological needs mediate the way they value an activity, so their priority in school settings is to fulfil their current psychological needs.

The conclusion of this substudy was based on evidence from two samples from different schools and teachers. Despite these contingent differences, the similarities revealed in the interviews further strengthens the conclusion. The fact that there is general agreement that the three basic psychological needs are considered as universal and guide the behaviour of all human beings should not be ignored. What SDT does not consider is that these three psychological needs could vary before the individuals’ engagement with an activity and could be responsible for creating individual differences. It can be claimed that some of the individual differences in the development of interest in a group of students who attend the same course could be explained by the bias they have for the degree to which it is possible for the course to fulfil their psychological needs.

This conclusion suggests that a science course (or courses of other subject matters) should be organised not only taking into the account the students’ prior knowledge to construct the new knowledge. Teachers should also take into the account that students entering the class may have different biases for which psychological needs and to what degrees the course could fulfil their three basic psychological needs. These biases mediate their interest and they personally find different activities interesting to them. Brophy (2008) suggests shifting from focusing on intrinsic motivation to focusing on how to motivate students to learn i.e., to find learning activities meaningful and worthwhile, even though they do not necessary feel pleasurable per se for the students. The conclusions of this substudy are in agreement with Brophy’s findings (2008), and provide more evidence for what constitutes meaningful and worthwhile activities for adolescents. As the emphasis on basic psychological needs of students in a class may vary, it is important to organise rich teaching settings to enable all students to experience teaching in a way that is compatible with their personal needs, so that each student could find out at least one reason to be actively involved in and enjoy the teaching. In other words, it is not sufficient to design teaching environments that provide general situational interest—it must additionally be specified for whom they are interesting. As classes are constituted on the basis of age and students with different motivation orientations are involved, instruction should take into account the different motivation orientations in the class and the different motivational needs that different students might have.
The conclusions are based on a small group of students and need further validation. Moreover, the phenomenological metacognitive experiences of the students are not identical with the original reactions to the activities that triggered their interest. Furthermore, the emotional signals from the actual reactions are partly subconscious and it is difficult to have real records of them.
11 Promoting science understanding and knowledge about STEM occupations with industry site visits

As already considered in the introduction of this research report, many students do not find science-related occupations worth pursuing and do not see themselves as potentially choosing a scientific career (Lavonen & al., 2008; Osborne, 2008; Tytler, Osborne, Williams, Tytler, & Cripps, 2008; Woolnough, 1996). A possible reason for this is the negative stereotypical and one-sided image about science-related occupations held by students (Christidou, 2011; Scherz & Oren, 2006; Schreiner & Sjøberg, 2005). Keeping this concern in mind, one aim of this research project was to familiarise students with occupations in the field of science, technology, engineering, and mathematics (STEM).

The fact that the sequence takes place outside the walls of the classroom is central to the design. In the literature, there are various examples of science education projects conducted in out-of-school settings, such as museums, science centres, university laboratories, special exhibitions, workplaces and events, as well as tours and field trips (Braund & Reiss, 2006; Braund, Reiss, Tunnicliffe, & Moussouri, 2008; Falk & Storksdieck, 2005; Griffin, 2004; Martin, 2004). In this out-of-school context, for example, students’ learning, interest and motivation, socialisation, and personal development have been researched. According to the synthesis carried out by Braund and Reiss (2004), access to ‘real’ science and technology can have an effect on both learning and interest and motivation. Even though this research was only about examining how to promote students’ motivation and interest, and not about conducting an intervention and then examining what students have learnt during it, it is important to show that the site visit teaching sequence actually promotes students’ understanding about STEM occupations and materials science topics. This demand is related to the aims of the design; the design solution has to be relevant and usable from both students’ and teachers’ points of view. Relevance for the student means that the design solution has to improve learning of science-related content and skills, whereas relevance for the teacher means that because time resources in science lessons are limited, no teacher wants to implement teaching sequences that do not promote the fulfilment of the aims of the curriculum.

In this substudy, the potential of the site visit sequence to promote science understanding and knowledge about STEM occupations is evaluated through
evaluating the change in students’ outputs (mind maps) before and after the sequence, and through the analysis of students’ interviews. Learning is considered in terms of the change in students’ outputs rather than change in the neural connections in an individual’s brain (Kalat, 2009) and the process of storing and retrieving information (Eysenc & Keane, 2010; Gazzaniga, Ivry, & Mangun, 2009), which cannot be investigated in the present research setting and methods. It is concluded that if there is significant improvement in a certain student’s output after the site visit sequence, this particular student may have adopted something during the sequence, or the organisation of the topic-specific knowledge structure of that student may have been revised. With this particular research design, other possible variables except the site visit teaching sequence influencing students’ learning could not have been controlled. As already noted, this research was not about conducting a memory retrieval experiment, but testing the potential of the design solution.

Bransford, Brown, and Cocking (2000) and Donovan and Bransford (2005) consider that the learning of new concepts is deeply context-bound. It is more likely that a new concept becomes a part of one’s knowledge structure if it is introduced in a varied range of contexts. The contextual aspect of effective learning is considered in this research by offering various approaches to science content, in the contexts of both classroom and the ‘real world’. With careful preparation before the visit and appropriate elaboration afterwards, an industry site visit is an example of encountering new concepts and information to be learnt in multiple contexts. Furthermore, an out-of-school context may make it easier to awaken and deepen interest in sciences, show how science and technology are applied outside the classroom, increase students’ knowledge about career possibilities within the field of industry, and even discuss how to integrate school disciplines (Brunton & Coll, 2005). Moreover, students may meet positive and diverse role models of people working in STEM occupations in a genuine environment, and they have the opportunity to engage in activities that are impossible to carry out within an ordinary lesson in the classroom. Based on large national survey data, Juuti, Lavonen, Uitto, Byman & Meisalo (2010) reported that students favour increasing the number of site visits and the use of experts in teaching. Guest speakers and educational site visits provide a starting point that is more authentic than traditional learning materials for becoming acquainted with the applications of scientific information, e.g., in technology and medicine. Finally, the principles of inquiry-based science teaching (IBST), which guided the design, should operate in favour of students’ learning. Minner et al. (2010) conclude, after reviewing 138 studies concerning inquiry instruction, that even though there is no statistically significant association between the number of inquiry aspects and increased student science conceptual learning,
students’ active thinking and responsibility for learning are associated with improved content learning; active construction of knowledge is necessary for understanding, as they put it.

As discussed in the Introduction and Chapter 4, motivation is one of the central elements of this research. The assumption of students’ individual differences and differences in their motivation orientation is found to be significant. This leads to an interesting problem: do students with different motivation orientations learn different things during the site visit sequence? What do they emphasise in the interviews? This is also stimulating from the point of view of differentiating teaching, which is strongly urged in the Annex of the National Core Curriculum (AANCCBE, 2011). In this substudy, the categorisation of students based on their motivation orientations and conducted by a cluster analysis of the AMQ results was employed; students were categorised into groups of amotivated students and students with controlled or autonomous motivation orientation.

11.1 Research questions of the third substudy

The effectiveness of the site visit teaching sequence from the point of view of the aims of the curriculum is examined by analysing students’ outputs before and after the visit, and by asking students themselves. The research questions are:

What was the difference between students’ outcomes before and after the site visit teaching sequence?

and

How did students with different motivation orientations describe their learning during the site visit sequence?

11.2 Data collection and analysis methods

Research question 1 is answered on the basis of students’ (age 14–15) pre- and post-mind maps. Research question 2 is answered on the grounds basis of student interviews. This substudy focuses on the cycles 1 and 2, during which students were interviewed and the mind maps were constructed. These cycles are selected because the researchers organised both the visits and the mind-map constructing situations. The final trial of the research was organised by the teachers independently according to their own schedules, and many of
them did not find time to organise the mind-mapping activities. In the following sections, the procedure of constructing mind maps before and after the visit and aspects related to students’ interviews are considered in detail.

11.2.1 Students’ pre- and post-mind maps

When considering how to examine the scientific content that students had learnt during the teaching sequence, it was decided that informal mind maps constructed by the students be used before and after the sequence. These mind maps were data-gathering tools, and they were different from the concept maps that were suggested for the sequence processing phase in Chapter 7. A mind map, in general, refers to an informal type of a graphical representation of the concepts in a student’s knowledge structure. The mind map is considered informal when compared to a Novakian concept map, for example. Before starting with the mind map task, students were given the company name and the commercial slogan, and three concepts: careers and occupations, materials, and products. First, students constructed mind maps in which they showed their pre-knowledge about the company they were about to visit. Students had trained in the mind map technique earlier, and they were familiar with converting their understanding into graphical form. Students were also given a couple of questions (such as ‘What materials are needed to manufacture a product in the company?’) that aimed at helping them to get started. On the basis of these three given concepts, students outlined mind maps of their own pre-knowledge. If they had not been told anything about the occupations in the technology industry within their career counselling lessons, some of them were a little frustrated with the task. Some even said that the map was ready before they even started.

After the site visit students constructed another mind map about the industry site they had visited. They were given the same concepts as before the visit: careers and occupations, materials, and products. Students’ outputs before and after the visit were compared to each other in order to determine if there has been any improvement as a result of the sequence. First, I went through the maps and became acquainted with students’ outputs. The concepts in the maps were listed. This was an appropriate method because the structure of the maps was very simple; there were three branches going from the middle (company name) in three directions (occupations, materials and products). A short description of each mind map was written. The focus of attention was on the relationship of a certain concept and the field of industry that the visit was related to, not so much on the relationship between a certain concept and the network of concepts in the mind map. But as mind maps are merely concept lists by their nature rather than networks like formal concept
Promoting science understanding and knowledge about STEM occupations with…

maps, it was decided that analysing the structure could receive less attention, and the concepts in the concept lists were divided into categories of ‘relevant’ and ‘irrelevant’. ‘Relevant’ in this context is defined in the next chapter.

The next phase was to decide how to make the distinction into relevant and irrelevant concepts. Another researcher and I generated analysis criteria based on the aims of the teaching sequence and the curriculum, and the instruction of the mind map task itself. The analysis criteria consisted of categories a) careers, occupations, education and business issues related to the company, b) materials used at the company and c) products manufactured at the company and their uses. We categorised the concepts of the mind maps independently from each other keeping the criteria in mind, and our results were compared. Each concept that was not categorised unanimously was discussed, and a consensus was reached. The most obvious reason to classify a concept as irrelevant was to deem it too general in the context of the particular company. An example of this was ‘boss’. It was considered irrelevant because almost every company has a boss (or more formally manager), and writing down ‘boss’ does not reflect any knowledge concerning a particular company. Additionally, those concepts that were not understandable, due for example to the language used, were categorised irrelevant, rather than being subject to an inexact effort to decode the meaning. Students might have had relevant concepts in their pre-maps due to their science lessons, studying the cross-curricular themes in the National Core Curriculum for Basic Education (NCCBE, 2004), or from the media or family discussions.

Students’ pre- and post-mind maps, more precisely the difference in the amount of relevant and irrelevant concepts in them were compared with a nonparametric Wilcoxon test. Wilcoxon Signed Ranks Test is a nonparametric equal to the t-test, for occasions on which the values of the paired differences are not normally distributed (Cohen, Manion, & Morrison, 2007). The pre-conditions for the use of the Wilcoxon test are that the measurements are conducted in pairs, that it is possible to say which one of the values in certain measurements is bigger, and that the distinctions between values can be organised based on the order of magnitude (Metsämäki, 2006). The differences must have been measured with an interval scale at a minimum. In this case, the measurement was paired or related (pre- and post-test design), the difference was measured in a ratio scale, and the values of the variable (number of concepts in the mind map) were not normally distributed.

11.2.2 Students’ interviews

The relationship between students’ motivation orientation and what they adopt during the sequence was of interest in this substudy, and therefore
students with different motivation orientations were chosen for interviews, following the procedure presented in more detail in Chapter 8. A representative from each cycle with features of a particular motivation orientation (amotivation, controlled motivation, autonomous motivation) was selected, on the basis of the AMQ, for interviewing; there were six interviewees altogether.

Students were interviewed according to a semi-structured protocol in order to understand better the aspects that students had adopted, based on their mind maps. The interview protocol was grounded in the aims of the sequence. In line with the relevance criteria of the mind map concepts, the interview questions concerned careers and occupations of the company, materials used at the company, and the products manufactured by the company. Learning about these aspects was the core emphasis when the sequence was designed (see Chapter 9). There also were additional questions concerning students’ view of their own mind maps before and after the visit. The aim was to examine what aspects of the visit students remembered and what they emphasised, and reveal students’ own view of their learning during the visit, all in relation to their motivation orientation. In the same interview, students were asked about their motivation to study science. These results are discussed in the second substudy. The interviews took from 20 to 29 minutes, and produced 8 to 13 pages of transcripts each, given that the motivation part and the learning parts were combined. The interviews were conducted after the construction of the post-mind map. Following the ideas of deductive content analysis (Tuomi & Sarajärvi, 2002), the analysis sequences were coded as to whether they illustrate the products, materials, and occupations related to the company, because those aspects were emphasised in the intended learning outcomes.

In the second part of the interview, themes that were selected as units of analysis were coded on the grounds of the aims of the sequence. The codes were occupations, materials and products. The results of that part of the interviews are discussed in this chapter.

I read the students’ answers several times. First, the interviewees’ utterances were associated with the category features mentioned above. Second, reduced expressions in English were composed after distinguishing the relevant issues from the ones focusing on something else, and encoded with the relevant category code in the analysis table. Students’ word-for-word quotations, the English translations of the word-for-word quotations, and the coded reduced expressions of these quotations were arranged in the analysis table. Finally it was confirmed that the categorisation agreed with the original Finnish expression.
11.3 Results of the mind maps and interviews

Because the mind maps in cycles 1 and 2 were constructed according to essentially similar instructions, the data was analysed together, and the interview results from both cycles were combined. On the grounds of the Wilcoxon signed ranks test, the number of concepts in students’ post mind maps that are relevant to the aims of the teaching sequence was significantly increased during the teaching sequence (Z=300, p<.05). The means of the whole sample and means of each motivation orientation group are presented in Table 15; the student group was analysed as a whole in this test. Even a cursory glance at Table 15, in which the means of relevant and irrelevant concepts in students’ pre and post maps are considered one motivation orientation at a time, indicates that the number of relevant concepts has increased, and the number of irrelevant concepts has decreased, from pre to post. The test was conducted in order to confirm the results statistically. However, because the research setting that was not controlled, it is not possible to say anything about causality between the site visit and the increase in the number of topic-relevant concepts in students mind maps. However, when comparing different motivation orientations, controlled and autonomous motivation orientations distinguish themselves from amotivation.

Table 15. Numbers of concepts in students’ pre and post mind maps. Means of different motivational groups and the entire sample.

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<th></th>
<th>Pre-map irrelevant concepts (mean)</th>
<th>Post-map irrelevant concepts (mean)</th>
<th>Pre-map relevant concepts (mean)</th>
<th>Post-map relevant concepts (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation (N=5)</td>
<td>6</td>
<td>2.6</td>
<td>1.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Controlled motivation (N=13)</td>
<td>8.4</td>
<td>5.7</td>
<td>1.6</td>
<td>15.3</td>
</tr>
<tr>
<td>Autonomous motivation (N=8)</td>
<td>9</td>
<td>3.8</td>
<td>3.9</td>
<td>11.5</td>
</tr>
<tr>
<td>Whole sample</td>
<td>8.2</td>
<td>4.5</td>
<td>2.2</td>
<td>12.1</td>
</tr>
</tbody>
</table>

The distribution of the concepts based on the categories in students’ post-visit mind maps are presented in Figure 3. Students remembered better aspects related to products and occupations of the company compared with materials that were used in the company.
11.3.1 Amotivated students

The mind maps of the amotivated students were the narrowest on the average based on the number of concepts in the maps (See Table 15). However, the two amotivated students that were selected for the interview were, somewhat surprisingly, quite talkative and had a lot to say about how they felt about the site visit. One of them (V1) was well aware of the materials that had been used in the company and what properties these materials had. She said:

…well I know that different materials are being used, like rubber, glass, iron and metals, aluminium and copper, and paper or cardboard…these things I learnt…

She also knew why certain material was chosen for certain use, and she referred to the properties of these materials. She explained:

...rubber he said is...this at least I remember...it is good because it is soft and it is easy to manufacture things of it and the glass, it is a bit difficult as it gets broken easily and it is difficult to mould...they have to be durable if someone buys a product that is very expensive it has to last long, about 15 years or so, I don’t remember so well, it has to tolerate hits well and heat and humidity and everything that may harm it...”

She also knew what the equipment was designed for:

...for measuring wind speed and direction and then air humidity and temperature and such...
One amotivated student (M1) considered the quality of the contents of her pre and post mind maps as follows:

"...well the picture before it is not such high quality information but then the one made afterwards, there is much more information about what there really is... at least the professions there are a lot more professions and then more things I could not have guessed...there are [post map] information with higher quality, such things that really took place in the visit that I now know...”

The mind maps of this student can be seen below.

**Photo 8.** Pre-visit mind map of one amotivated student.
Anni Loukomies

Photo 9. Post-visit mind map of one amotivated student.

The site visit gave students a glimpse into what the actual work is like. One amotivated student (M1) emphasised the value of an out-of-school visit to her understanding:

...there should be more things like this because when the students see themselves how things are done and then if someone is really interested in these industrial issues like a welder’s occupation or an assembler’s, or these topics then they get to see themselves with their own eyes and not just watching from TV because it is completely different to see it yourself...

Also another amotivated student (V1) valued the possibility see the processes on-site. She said:

...it was probably my own experience because...well the teacher explained the topic quite well but still you understand things better when you see...well in my opinion it was nice because...I usually learn better when I get to see and try things myself...in there I got to listen and speak [to personnel] and then see those things so it was a good choice...

One amotivated student’s (M1) understanding also expanded from just a product to the whole manufacturing process that creates the final product. She said:
...when we went downstairs to look how this metal work is done, what are the processes like, it was really interesting because I never saw it done before, I only thought it is melted and moulded. But then I saw it welded and polished and there may be a million processes more but I don’t know what they are but robots are doing the job...

Another amotivated student (V1) also described the processes observed:

...in there they have to braze all those transistors and things together and small machinery is used, or the machines are for the smallest tasks if there is something that cannot be done by hands, but something is also done by hands...

11.3.2 Students with controlled motivation

On average, there were large numbers of concepts in the mind maps of students with controlled motivation compared to other motivation orientations (See Table 15). Students with controlled motivation tried to explain processes they saw at the visit using what they had learnt at school, and they primarily recalled products that somehow sparked their interest. One student with controlled motivation (V2) remembered best the radiosonde that was demonstrated in the visit, and that the students were asked to help launch it. This student also remembered well the person who gave the presentation, but the details of the presentation were not so well recalled. She had vague recollections regarding education and that many kinds of skills must be possessed, but she could not explain them in detail. An example of her view follows:

...well I don’t know what they were doing but yes, I saw their people working, some of them were loading the mast to be taken somewhere, to the Caribbean or somewhere, and then, one was showing us the computers in which the radiosondes were shown, so probably he (she) is doing something... some high level education from somewhere and probably there were also basic level education, I don’t know where one should study to get to work there, probably chemistry and physics and whatever they are, and then, of course if you go travelling you have to possess language skills to be able to deal with people, communication skills...

The ideas of another student with controlled motivation (M2) were similar in terms of the level of detail. He said:

...well there were just like the ordinary employee there who works with the device and then, I don’t remember the professions very clearly but it was some kind of director...director was there but I don’t remember correctly those...they had gone to some university and from there then...well they told there that they can travel somewhere those who sell the valves he told that he may have to go abroad to sell the products and with them... was it the marketing director or something ...well the marketing person he has to speak different kinds of languages and has to know about the economic issues of the company.
This student analysed the process of constructing mind maps as follows:

...well I have found more thoughts and I remember it was easier to write, well it was just easier when you did it already once and it was easier then to gather new thoughts...it was easier afterwards to construct the mind map...

Photos 10 and 11. An example of pre- and post-mind maps of a student with controlled motivation orientation. Pre map above, post map below.
11.3.3 Students with autonomous motivation

Students with autonomous motivation gathered new information about the properties of materials, and that certain material was chosen for certain uses due to its properties, but in a much more specific way than the amotivated and controlled motivation students. The post-mind maps of these students improved in terms of the quality and relevance of the concepts chosen for the maps. An example of their detailed way of describing follows (M3):

...for example there different kinds of flow control devices these valves, in there they showed different models of them and computer software was told about, and, in fact, there actually was nothing else...the place we went was about flow control systems...we were discussing with the material engineer I don’t remember his title but, however, he said that there are about 20 metals, basic and then about 100 special surface covering materials...

The other interviewed student with autonomous motivation (V3) also had a detailed understanding about the materials used in the company:

...metals, I mean aluminium, and plastic in the covers and then copper is quite often used in the circuit boards and wires and conductors, and then of course rubber is the insulating material and then cardboard is the packing material because those [the device] are transported and stored in cardboard boxes...

Similar detailed descriptions were found when another student with autonomous motivation spoke about occupations at the company (M3):

...there were collectors, personnel managers, engineers in general, welders and everything related to metal industries and electric industries also...most of them had an engineer’s education, of course different kinds of engineers, electric engineer, machinery engineer, metal engineer or something, and graduate engineer...well, for example the device collector had the fine tuning to put the small parts of the device together, and the product engineer is responsible for what is done, and then there are, of course the designers who design with a computer and then, of course if you are a welder, for example, [you have to know] how a certain metal acts in a certain temperature and in general, how certain materials and substances act in certain circumstances...

Another student (V3) also remembered many different occupations:

...the majority of them, or about a half, were engineers...eclectic engineers, and then there were those in the commercial sector, salesmen and then at least one PR person who gave us the presentation, and then there are all kinds of packers and kind, less well-paid jobs... they were...was it 60% engineers, three with doctoral degree and then there were...I don’t remember the percentages but quite many with vocational level degree in business...

One student (M3) noted on his own that his knowledge structure had gotten more detailed and precise during the visit. He said:
…well for example this Metso automation had this adjusting device for industry, so at first I considered all kinds of adjusting devices but they are for flow control, current flow, water flow, air flow and so... valves and such, computer software... so my view became more precise about products that they do not produce all kinds of adjustment devices but they have specialised themselves for just some of them... and then also the knowledge about professions expanded...

Below there are two examples of pre and post mind maps of students with autonomous motivation orientation.

Photo 12.

Photo 13.
Photo 14.
Photo 15.

Photos 12, 13, 14, and 15. Two pairs of pre and post maps (12 and 13, 14 and 15), created by students with autonomous motivation orientation.
11.4 Discussion

The interviews revealed that amotivated and controlled students had constructed a less detailed view of the site than those with autonomous motivation. The highly-motivated students may have constructed some kind of topic-related knowledge structure even before the visit sequence, and thus it was easier for them to recall also the details in the interview situation. The high-quality motivation may also be related to students’ better organisation of information and thus more effortless retrieving. Besides the products, materials, and technological applications of science, students gathered new information about work life, environmental issues, and recycling materials in the company. Some of the interviewed students remembered that there are professionals from various fields working in technology enterprises, and that some kind of, vocational or university level education is needed, and that employees of the company must possess many different kinds of skills. This is very important, especially from the point of view of the amotivated ones, who might have difficulties in seeing the relevance of their science studies. In an authentic situation, they saw how the whole range of skills taught within different school subjects is utilised.

The data collected for the purposes of this substudy offers one view into the evaluation of the developed teaching sequence. Here, the focus is on the intended learning outcomes related to learning of properties, use, and manufacturing of materials and artefacts and, moreover, to students’ knowledge about STEM occupations and the education needed for those occupations. Based on the results of this substudy, it is argued that a site visit teaching sequence that is designed according to principles of the IBST, and that encompasses features that promote students’ responsibility, active thinking, and motivation, has a positive impact on students’ outputs in the context of materials science. The statistical parameters show significant increase in the amount of topic-relevant concepts in students’ post-visit mind maps compared to those created before the site visit sequence. If the increase in these concepts is interpreted as a proof of learning, then it can be concluded that most students have learnt materials science-related information during the sequence. Of course with this research design it cannot be guaranteed that there were no other variables that influenced the results, but it is unlikely that the students had gathered the information concerning the company they visited from some other resource completely divorced from the visit. Taking these conditions into account, it is concluded that the improvement in the mind maps is an indication that learning has taken place.
When collecting data with mind maps, a pre-post design was applied, but the interviews relied retrospectively on what students remembered about the visit. The questions may have guided students thinking, and important aspects outside the scope of the questions may not have emerged, as no one asked about them. In general, the teenage participants had difficulties in expressing their thoughts in spoken words, and many found the interview situation exciting. It might be claimed that a control group would have clarified this issue, but as the design and research takes place in an authentic setting, it is difficult to distinguish the different variables of the learning situation and manipulate only them, as would be required in a control group context. Even though the visit was in a focus in this sequence, there were also many features of ordinary teaching taking place. Moreover, the design process proceeded simultaneously with the research, and formative evaluation of the collected data guided the design, so there was no refined intervention to be tested. Emphasising the scrutiny of the post-mind map in the interview situation and videotaping this conversation so that the mind map could also be seen might be an improved means of gathering information of the students’ re-formulated knowledge structure concerning the occupations, materials, and products encountered during the teaching sequence.

The sequence seems to be a reasonable way of promoting studying in authentic contexts. The careful preparation before and elaboration afterwards enhances learning of scientific concepts and introduces methods of applying scientific knowledge in real world. This follows the ideas of Storksdieck (2001), as he argues that the students’ preparation phase and examination of students’ prior knowledge and attitudes, and a follow-up are essential to connect the visit successfully to the curriculum. If prepared carefully beforehand, and elaborated further after the visit, an out-of-school visit is a good example of encountering new concepts and information in multiple contexts. Activities that the students carry out in the classroom before the site visit should help the students to deepen their understanding about the science-related topics they will observe during the visit (Astin, Fisher, & Taylor, 2002). Kisiel (2005) argues that such a connection encourages the teacher to organise out-of-school visits, and helps to see the benefits of the visit from the point of view of the planning the teaching sequences.
12 Overall discussion

This dissertation has been an interaction between design and research. Central to this design-research project was applying a motivational theory, SDT, into a pedagogical sequence and testing that sequence. A teaching sequence was designed for school science in order to enhance students’ motivation for and interest in science learning, to break their stereotypical images related to science occupations and their own possibilities in those fields, and offer them a new perspective that combines what they have learnt at school with life outside the school. As the students see the additional aspects of science compared with those they may have seen in the classroom, their feelings of personal relevance of science studies may increase, and they may become more motivated and interested in studying science. Another aim for the design was to generate a phenomenon to be investigated in the research stage by implementing the designed sequence. The aim of the research was to examine which particular aspects of the design have appealed to particular students and enhanced their motivation and interest, and what students have learnt within the project. Special emphasis has been placed on students’ distinguished motivation orientations.

In this section, the multifaceted design-research project is discussed from the following three perspectives: firstly, evaluating the quality and trustworthiness of the research; secondly, the design solution and the process through which it was generated; and thirdly students’ motivation and interest in the context of science education. Finally, the aspects that arose during this research project, but that are too extensive to be included in this report, and challenges for future research are discussed briefly.

12.1 Evaluating the quality and trustworthiness of the research

The paradigmatic commitments, background, and purpose of the research outline the criteria on which the quality and trustworthiness of the research should be evaluated (Patton, 2002). For example, the traditional scientific research criteria of assessing the quality of a certain research—namely the concepts internal and external validity, reliability, and objectivity—arise from the positivist research paradigm that builds on the assumptions of objectivism and a view of truth as a representation (Niiniluoto, 2002). Based the ontological differences, Guba (1981) classifies research paradigms as rationalistic and naturalistic, the former resting on an assumption of truth as repre-
sentation, the latter resting on the antirepresentational view of truth. According to Guba (1981), the four aspects of trustworthiness that are relevant from both the rationalist and naturalistic perspectives are truth value, applicability, consistency, and neutrality. However, depending on the paradigm, they are demanded to different extents. In conventional scientific research, internal validity is related to truth value, external validity or generalizability to applicability, reliability to consistency, and objectivity to neutrality. Various quality criteria have been proposed to be used when evaluating research that is not based on positivist tradition and thus cannot be evaluated with the traditional standards. Guba (1981) proposes replacing the term internal validity with credibility, external validity with transferability, reliability with dependability, and objectivity with confirmability. Denzin and Lincoln (2005) and Patton (2002) further argue that the trustworthiness of research building on the constructivist tradition should be evaluated in terms of credibility, transferability, and confirmability.

In this thesis, the criteria for the quality and trustworthiness of the study have been chosen on grounds of the paradigmatic commitments rather than on grounds of methodological choices. Pragmatist and constructivist paradigms share an antirepresentational view of truth and value the subjective and intersubjective experiences of individuals (Biesta & Burbules, 2003; Denzin & Lincoln, 2005). This ontological difference makes it inappropriate to evaluate a piece of research that builds on a pragmatist or constructivist paradigm with criteria emerging from the positivist paradigm. Besides the antirepresentational view of truth, action is considered important in the writings of the significant characters of constructivism and pragmatism. One explanation offered is that both paradigms root from the same philosophical background (Miettinen, 2008). The trustworthiness of this piece of research is scrutinised on the grounds of quality criteria proposed for naturalistic paradigms (Guba, 1981; Denzin & Lincoln, 2005; Patton, 2002). Besides these, Edelson (2002, 2006) has suggested quality criteria for DBR. First of all, a design-based research project must aim at yielding insight to some important need or problem. Then, from the research point of view, the design must be grounded in prior research, it must be carefully documented and formatively evaluated in order to steer the iterative cyclic process, and the results must be generalizable. From the design point of view, what is the novel innovation? Is it useful? These sets of criteria overlap at some points and therefore will be discussed in parallel.

As noted, trustworthiness of the research has to be evaluated from the perspectives of credibility, transferability, dependability, and confirmability (e.g. Guba, 1981; Lincoln & Guba, 1985). Credibility is concerned with the question of whether the research results are congruent with reality (Merriam,
In qualitative approaches, the understanding of reality is really the researcher’s interpretation of participants’ understanding of the phenomenon of interest (Merriam, 2002, p. 25), and thus tracking this understanding requires extra care. Patton (2002) argues that three aspects need to be considered when aiming at increasing the probability of credible findings. These aspects are methodological rigor, the credibility of the researcher, and commitment to the qualitative paradigm that means appreciating holistic thinking, purposeful sampling, and qualitative methods in general. Methodological triangulation is one means of decreasing biases in the results (Merriam, 2002).

In this study, both qualitative and quantitative methods were used, and conflicts between the results they yielded were scrutinised carefully. The analysis of the ESIAQ did not reveal any statistically significant differences between how the students felt about the teaching sequence when compared with their usual way of studying science. By contrast, the interviews revealed that despite their motivation orientation, students preferred the site visits to ordinary science lessons, and none of them would have chosen to stay at school instead. It can be concluded that the questionnaire failed to grasp the students’ experiences fully. The reasons may be the wording of the questionnaire or the time the questionnaire was employed, or a combination of both. Although statistical methods did not reveal any differences between the teaching sequence and ordinary science teaching, the qualitative method of the interviews certainly did. However, interview as a data collection method is open to interviewer bias (Cohen, Manion, & Morrison, 2007). These biases have been controlled by carefully transcribing the interview tapes and by employing researcher triangulation.

Additionally, some theory triangulation has been employed; besides the SDT, students’ motivation orientations were considered also from perspectives of other motivation theories in the discussion chapter. Technical rigor has been employed in the data collection, analysis, and reporting phases. The clustering of students in the data collection phase poses a threat to the credibility of the research. Counting the percentages of the number of students in different clusters one cycle at a time deviates remarkably from the percentages counted on the basis of the whole sample (29 students). However, given that the data-gathering was a primary tool for redirecting the design, the clustering and the subsequent interviews had to be conducted immediately after each cycle. It must be kept in mind that students are categorised as amotivated in relation to their own groups.

Researcher credibility is a vital element in research with integrity. The principle in increasing the credibility of the researcher is to report any personal and professional information that may have affected data collection, analysis, and interpretations (Patton, 2002, p. 566). This includes detailing
the roles and affiliations of the researcher in relation to the aims of the study. Regarding this research, these aspects are discussed in Chapter 9, which describes the different cycles of the design-research process. Patton’s final demand for credibility proposed by Patton (2002), appreciation of the qualitative paradigm, is built into the research, because all decisions have been made on grounds of the paradigmatic commitments. A science class setting is an example of a dynamic system composed of multiple parts, each with its own functions but also involved in a pattern of reciprocal influences with other parts (Schaffer, 2006). It is important for the researcher to understand that a naturalistic approach is relevant for researching authentic phenomena, and if some aspect of the site visit sequence had been isolated and examined in a strictly controlled setting, the results probably would have failed to grasp the dynamics and interdependence of the components in a real school atmosphere.

Another aspect of research trustworthiness is transferability; the question is to what extent the findings can be applied in other situations (Merriam, 2002). Rather than considering how certain results emerging from a random sample may be generalised to a population with a certain probability in a positivist sense, it should be considered what can be learned from an in-depth analysis of a particular situation and how that knowledge can be transferred to another situation (Merriam, 2002, p. 28). Edelson’s (2006) criterion of generalizability should not be understood in a purely statistical sense but rather as a synonym for transferability of findings. The focus of the research must be expandable beyond the current design setting to other contexts. Through retrospective analysis, problem, solution, and processes of design need to be seen as instances of more general classes. Through the process of generalization, the elements of the design process are developed into useful, more general theories (Edelson, 2002). Furthermore, the theories that result from DBR projects are not justified on the grounds of being interesting theoretical constructions but to the degree to which they accomplish pragmatic results in complex real-life settings (Cobb, Confrey, di Sessa, Lehrer, & Scauble, 2003). However, there is a paradox: even though the complexity of a real-world context highlights the need for an effective theory, that same complexity makes the development of useful theories much more difficult (diSessa & Cobb, 2004).

The design solution of this DBR project as such is topic-specific, in this case materials science, but the idea and procedure of the teaching sequence are transferable into the contexts of other school subjects. The transferability of this particular design solution has been enhanced by implementing the particular design solution many times in Finland and even on one occasion in Greece. The Greek implementation is considered here only from the point of
view of transferability, to detail the fact that the design solution was functioning quite well in a completely different educational setting. The Greek implementation is considered more carefully in a paper by Loukomies et al. (2013). According to the external evaluators in Greece, despite the completely different context and school culture, the implementation was a success, so the sequence can be said to be transferable within the European context, at least at some level. This is very valuable, as the adoption process of new skills and knowledge in the new context may be problematic, because it is known that it involves an interrelated series of personal, cultural, social, and situational factors (Rogers, 2003). The external evaluators certified that the two implementations had similar elements concerning the scientific, educational, didactic, and motivational characteristics.

The Student Book and the Teacher Guide are concrete outputs of the research, and they can be used to the extent that they fit into a teacher’s plans. The new knowledge generated about motivation, interest, learning science in out-of-school settings, and an interdisciplinary approach in relation to theory-based instructional method and authentic context is transferable from the science education context into education in a broader sense. For the successful transfer of the sequence, it is necessary that the designers, when they distribute the sequence, focus their efforts and interest on the essential characteristics (psychological and educational) of the sequence, being flexible and willing to change characteristics of minor importance.

A challenge for DBR lies in finding a balance between refining a particular innovation in order to maximise its success, and generalising findings to a different set of conditions (DBRC, 2003). The context-bound nature of design research explains why it usually does not strive toward completely context-free generalisations. The need is to determine the factors that result in the desired outcome. In this case, the characteristic features are learning activities that support the fulfilment of students’ psychological needs and the industry-related out-of-school context.

The aspect of trustworthiness that equals reliability within the positivist paradigm is dependability. Reliability means that the findings of the research should be replicable by another researcher. However, according to Merriam (2002), the demand for reliability in social sciences is problematic because human behaviour is never static (p. 25). He finds it more relevant to ask whether the results are consistent with the data collected. Besides being reliable, dependable findings of the research are also trackable by the reader. This means that the readers can authenticate the findings by following the researcher’s path (Merriam, 2002).

This demand fits well with the requirement for systematic documentation of a DBR process, in order to support retrospective analysis. Traditionally,
however, this has not been called for in educational research the way it is in, say, engineering disciplines. The implicit elements of the design must be made explicit, perhaps by documenting them in a research log. The design process must be documented so that it can serve as an object for public reflection and discussion. This means documenting both successes and failures (DBRC, 2003). Careful documentation is also the key to sustaining trustworthiness in the phases of gathering evidence and reporting it. Documentation is also central in controlling bias, because the research setting can be highly dynamic and flexible and the researcher is thus highly personally involved in the context.

An innovative design process is open-ended, relies on creativity, conducts a systematic search in and through a particular solution space, and is a sequence of decisions made to balance goals and constraints (Edelson, 2002). Being so complex, context-bound, and multifaceted, DBR interventions cannot be precisely replicated (DBRC, 2003). Furthermore, because design research interventions and settings are naturalistic, scientific rigor may sometimes be difficult to maintain (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). In many effective designs the design processes are flexible and dynamic, meaning that the entire procedure cannot even be described properly until the design process is completed (Edelson, 2002).

The researcher’s track in this research is at its most explicit form in Chapter 9, in which the design-research process is described and evaluated. Sometimes decisions concerning the procedure were prepared during very informal discussions, e.g., when walking from the school to the parking lot. According to the guidelines for recording observations when conducting case study research (e.g. Cohen, Manion & Morrison, 2007), the decisions and ideas generated in such conversations were written down as soon as possible, as forgetting details accelerates as more time passes.

Confirmability refers to the fourth aspect of trustworthiness proposed by Guba (1981), neutrality. In qualitative paradigms, given that there are multiple realities and furthermore, multiple value systems, neutrality as objectivity may be difficult to require because subjectivity is built into the qualitative paradigm. Instead of objectivity, Guba (1981) and Lincoln and Guba (1985) propose using the term ‘confirmability’. One method, again, is triangulation that may and thus correct reveal biases in the data and interpretations. A DBR process, being theory-driven, can also be seen as a demand for confirmability. In the initial phase, DBR projects must be informed by the theoretical findings of previous peer-reviewed research findings in order to be able to yield useful results. Furthermore, DBR projects should be guided by explicit research goals. In other words, the designers’ world must be connected with both research findings and research perspectives. Designers should also be
aware of any reliance on intuition, incomplete theories, or informal knowledge, and such bases or assumptions should be documented as well. Finally, they should be aware of any gaps in the current understanding of the problem in question. Theory also guides data collection and analysis.

The commitment to use a theory-driven design generates complex interventions that can be improved through empirical study (DBRC, 2003). The demand of anchoring the design in theory has been taken into account in this project; research and design were grounded in the self-determination theory (SDT) of motivation (e.g., Ryan & Deci, 2002), theories of interest (e.g., Hidi, 2006; Krapp, 2007), and theories of learning in general (Bransford, Brown, & Cocking, 2000), learning in out-of-school settings (e.g., Braund & Reiss, 2004), and learning through inquiry activities (e.g., White & Gunstone, 1992). Features emerging from theories of motivation and interest are included in the design solution. In addition to the design stage, theory guided the data collection and analysis phases. Theoretical concepts were operationalized by ‘translating’ them into students language in the questionnaires and interviews.

Formative evaluation is also a significant tool in the pursuit of neutrality in design-based research, because it can identify inadequacies in the elements of the design process. A tightly integrated process of design, evaluation, and revision enables designer-researchers to identify problems or gaps in their understanding. Formative evaluation (e.g., evaluation discussions, external evaluations by experts, and student evaluations) expose issues the design-researcher must address. In this particular DBR project, aspects revealed within formative evaluation justified the decisions and changes. After each cycle of DBR, the analysis of the data collected within the cycle, the coordinated teacher-researcher conversations, researchers’ discussions, and external evaluators’ observations helped to identify weaknesses and inadequacies in the procedure, and afterwards these inefficient aspects were either revised or rejected. The inquiry tasks, for example, were modified to encompass models of materials to be used as background information in the tasks. The inquiry tasks also aimed at focusing students’ attention on the important aspects of the materials from the point of view of the company.

From the design point of view, the process starts from recognizing some issue that needs to be improved. Above all, the artefact needs to be pedagogically relevant and usable; these two criteria justify its very existence. Pedagogical relevance means that the artefact has to fit the contemporary view of learning in the context of science education. In this report, the pedagogical relevance and usability are considered from the perspectives arising from literature, and users’ (students’ and teachers’) perspectives. Alternatives to the current (problematic) practices and how these alternatives can be generated and sustained (Edelson, 2006) need to be examined. The demands for
novelty and usefulness of the design were fulfilled in this research, as there was new knowledge generated about how to appeal to students of different motivation orientations with out-of-school visits and about organizing site visits and combining science teachers’ and language arts teachers’ professional competence to approach the out-of-school setting from an interdisciplinary perspective. The ultimate usefulness of the research might be evaluated based on its practicality for real users, i.e., whether teachers adopt the design solution or not (DBRC, 2003; van den Akker, Gravemeijer, McKenney, Nieveen, 2006).

The design aspect typically brings some uncertainties to the picture: a new practice cannot be described and defined explicitly because it does not yet exist in the beginning phase of the research. Recognising and explicating all the variables concerning the phenomenon under examination is very difficult or even impossible. Although the novelty of an innovation involves risk, the fact that theory grounds the innovation reduces the risk into a tolerable scale and eliminates irrational excesses. The theoretical perspective thus helps put the innovation in context by scrutinizing the innovation through the lenses of prior theory. As Walker (2006) states, theory is the guarantee of the quality of these innovations. Research that takes a somewhat bigger risk of a false conclusion may have greater reward. For example Wang & Hannafin (2005, p. 6) have aimed at being systematic but flexible in their definition of DBR. The objective of design research is different from the objective of traditional experimental research. Therefore the results yielded by these two approaches are not easily comparable and should not be judged by the same standards (Edelson, 2002). However, the demand to be rigorous in order to be plausible and pragmatic is a challenge that must be taken seriously. An oversimplifying or ‘anything goes’ approach is not acceptable (DBRC, 2003).

12.2 The design solution: The site visit teaching sequence for science education

A teaching sequence was designed that is an application of particular motivation and interest theories in the context of science education. The design solution (industry site visit teaching sequence with motivational features) was designed in order to research a certain phenomenon, namely student motivation within the context of industry site visits. Without this specific design solution, this particular phenomenon could not have been investigated. The design took place in iterative cycles; during the process, the design solution was revised in order to better facilitate students’ motivation and interest. The decisions about revisions were made on the grounds of the data that was
collected during the cycles. This research yields novel knowledge about facilitating different students’ motivation towards science studying with industry site visits. This is discussed in more detail in the next subchapter that concerns the research side of this project. Besides the novel knowledge generated through the process, the co-product of this design-research project is the pedagogical sequence that can be transferred into other contexts. The materials related to the sequence, the Student Book and the Teacher Guide, can be downloaded from a website.

DBR appears to have been a suitable approach for developing the teaching sequence, especially because of its cyclic nature. Such a multifaceted structure would have been impossible to construct without an iterative element. Many essential aspects, such as the most effective way of setting the instructions for students or practical issues concerning the organisation of the site visits, were revealed only when through testing the sequence in an authentic school environment with different teachers.

According to a synthesis constructed by Minner, Levy & Century (2010), a given instruction can be classified as inquiry if it emphasises students’ responsibility, active thinking, and motivation in at least one of the phases of the instruction. In this designed teaching sequence, students were responsible for scrutinising the background information about the company on the web, deciding about the perspective of their article according to their interests, planning the relevant questions in order to gather appropriate data and adequate information, choosing the people to be interviewed during the visit, making notes, and processing the data collaboratively into article format. In the interviewing situation on the site visit, the students’ responsible role was most obvious. The teenaged students, who during their science classes at school were sometimes not overly willing to take responsibility for their learning, displayed real maturity when they had the chance to talk with the company professionals in the way that adults speak with each other, with the teacher not interfering in the situation.

Students’ active thinking was emphasised in the reporting phase, as they planned their articles and data collection and especially in the process-writing phase. During the reporting task, students scrutinise more deeply different elements of technology and industry, and examine the ways that scientific knowledge is applied in real-life contexts, and, finally, how it relates to employees’ everyday activities. Creating a written work is a complete process which involves students in transmitting ideas—through reading, organising ideas into sentences and paragraphs, putting them into logical order, supporting main ideas and points with a few key details, drafting, and editing. As this work was performed in collaboration with others, students continually needed to challenge their own views and work at adopting their peers’ per-
Anni Loukomies

spectives in order to reach a compromise. Collaboration with the language arts teacher is highly recommended in this phase.

Students’ motivation was supported with the theory-based features that were included in the procedure. Giving students the responsibilities introduced in the previous paragraphs supports their need for autonomy; all tasks were conducted in collaborative groups. This strategy aimed at supporting students’ feeling of social relatedness, while feedback from the teacher and peers had the potential to enhance students’ feeling of competence. Finally, students’ curiosity was nurtured by studying in a stimulating and authentic context enriched by the opportunity to meet interesting people working in the field.

Beyond the skills related to traditional school subjects, students practiced interdisciplinary skills introduced by Drake and Burns (2004), such as thinking and research skills. As described above, the teaching sequence aims at increasing motivation and interest in science learning, increasing students’ awareness of and interest in science and technology careers, and guiding students to encounter materials, like paper, metal, and plastics in various situations and contexts. A number of teaching methods are needed to realise these aims. These methods are introduced more explicitly in the Teacher Guide, and an in-service course is recommended to encourage the science teachers in applying methods that may be new to them. An industry site visit introduces students to the broader societal side of science, enhancing students’ awareness of science and technology occupations, and finally increases students’ understanding of the relevance of their own science studies. Moreover, an industry site visit offers students the opportunity to see how materials are used and it demonstrates certain properties of how materials are used in industry. When examining the occupations in the field of science and technology, close collaboration between the science teacher and the career counselor is recommended.

The inquiry activities connect the content of the visit with materials studied at school, so that the visit and school study support each other, and students have a fuller picture of the use of materials and professionals working with those materials. Inquiry activities offer a context for appreciating the properties of materials and the use of model-based reasoning. The Teacher Guide offers the teacher explicit guidelines for organising the inquiry tasks. Despite careful refining and redesigning of the teaching sequence, the multifaceted nature of the entire process remains a challenge for implementation. The teacher has to adopt various new teaching methods, some of which may not be in within the normal bounds of a science teacher’s expertise. So, in-service training or another type of mentoring would likely facilitate and encourage teachers to support students’ motivation and interest in the way that
is described in this study. Without such guidelines, there may be a risk of just checking off a list of tasks, concentrating on the product (e.g., the report) rather than the process. The Teacher Guide introduces ways that different objectives may be approached with different teaching methods. Consequently, the teacher should be familiar with the essential features of the teaching sequence, in order to implement it effectively; companies may have a strong, already existing idea about what a site visit should be like and what the students should be doing during these visits, so the teacher needs to make sure that the sequence goals remain paramount. It would be best if pairs or groups of the science teacher, language arts teacher, and career counsellor implement the teaching sequence in close collaboration.

According to the analysis of the AMQ data, there are differences in students’ science-related motivation orientations. The National Core Curriculum strongly suggests taking students’ individual preconditions into account in teaching (AANCCBE, 2011). Not all students plan to be future scientists, but all of them still should be equipped with some basic level of scientific understanding. The old slogan ‘science for all’ is a manifestation of this approach (e.g., Hodson, 2003). Additionally, the PISA evaluation of the OECD emphasises basic scientific literacy skills that all students should possess (OECD, 2006). At the same time, the interests of potential future experts in the field of science must also be considered seriously. The title of a recent publication by the EU makes this need explicit: Europe needs more scientists! (EU, 2004). It is a challenging task for a science teacher to, on the one hand, supply all students with a sufficient level of scientific understanding and on the other hand nurture the potential of future experts to develop and flourish. Teachers may find it challenging to differentiate teaching time so as to offer meaningful tasks for everybody at the same time, from those who may not be motivated to learn science at all to those who may be intrinsically motivated to investigate scientific phenomena. The teaching sequence introduced in this research facilitates, naturally and effortlessly, the differentiation of science teaching. As the main task of students is to gather data in order to report on a certain aspect of the site visit, students may choose either easier or more difficult topics for their articles and then scrutinise the topic as deeply as they wish. Given that the sequence takes place in an authentic context, students’ feeling of the relevance of science studies should improve.
12.3 Motivation and interest in the context of science education

In this research, students were categorised on the grounds of their SDT-based motivation orientation. There are also other ways of categorising motivation orientation. As introduced in Chapter 4, there are differences in the foundations of motivational theories, on the grounds of whether motivation is seen merely as a result of certain socio-cognitive factors influencing an individual, or as a result of an individual seeking for the fulfilment of the basic psychological needs (Pintrich, 2003; Ryan & Deci, 2002). Viljaranta et al. (2009) conducted a study in the theoretical context of the expectancy-value theory of motivation constructed by Eccles (see e.g., Pintrich et al., 2003), and that employs a more cognitive view of the generation of motivation compared to the SDT view (see also the Introduction Chapter). Grounded on the expectancy-value theory, Viljaranta et al. divided lower secondary students into six categories based on how the students value tasks at school. 38% of the students were multi-motivated, meaning that they valued all school subjects, 15% valued especially science and maths very highly, and 6% of the sample were low-motivated.

Even though expectancy-value theory conceptualises the generation of motivation differently than SDT, motivation is still essentially the same phenomenon, and it is instructive to compare those results with the ones in this thesis. When considering the sample and cluster analysis of it as a whole (combining samples from the first and second cycle), 9 students of 29 (34%) were categorised as autonomously motivated when it came to science learning. The high percentage compared to the percentage of science-oriented students in Viljaranta et al.’s study may mean that the group of autonomously-motivated students in this study consists of those who are genuinely motivated to study science in particular but also includes those who are motivated at school in general and interested in all school subjects (the multi-motivated). On the other hand, of the entire sample of this study, 21% of students were categorised as amotivated, whereas Viljaranta et al.’s found that 6% were challenged to find motivating aspects in the school work. So the amotivated group in this study may consist of those that are not motivated to study science and those who are not motivated to study at all. The latter group is an alarming one, because according to Viljaranta et al.’s main conclusion, adolescents’ task value patterns predict their subsequent school track and occupational aspirations. The consequences of a lack of motivation to study and inability to take responsibility for one’s own actions can be seen throughout society, such as number of students that do continue their education past their comprehensive school or do not even complete their secondary
Overall discussion

This issue makes the opinions of the amotivated students in this study especially important when considering effective methods of increasing their feelings of relevance about school and planning their educational future.

Additionally, the difference between students with controlled motivation orientation and autonomous motivation orientation merits further discussion. Even though also those with controlled orientation may be hard-working and dogged in their studies, it has been shown that studying merely for the sake of high grades and competing with peers does not promote well-being (Tuominen-Soini, 2012). Finding methods to facilitate the process of internalising behaviour regulation improves the quality of students’ motivation and promotes their learning results and well-being (Guay, Ratelle, Chanal, 2008; Vasalampi, Salmela-Aro, & Nurmi, 2009).

It is important to note that even though statistical methods did not reveal any significant difference between the site visit sequence and the ordinary way of studying, neither was the visit experienced more negatively than ordinary lessons. Students did not find the site visit teaching sequence to be a waste of time, but rather found it a relevant and engaging method of science learning. The fact that the teaching sequence appealed to the full range of students regardless of their motivation orientations is a productive starting point for future designs of interdisciplinary teaching-learning sequences in out-of-school settings. Especially remarkable were the amotivated students’ positive expressions about the sequence, after having seen the connection between what is studied at school and science applied in authentic settings. These students are the most challenging from the teacher’s point of view, because if they are not motivated to study, they may channel their energy into some undesirable activities that have a negative on the classroom atmosphere.

We still have to ask how permanent the effects of such a sequence are on student motivation and interest, from the point of view, for example, of students’ future career choices. Lott (2003) argues that such short-term interventions cannot generate permanent changes. There is a need to consider carefully how the effectiveness of an intervention is measured and assessed, as there may be benefits on the scale of the individual student that cannot be tracked with broad statistical methods. However, there is definite a need for evidence of the longer-term effectiveness of these interventions because they require special effort on the teacher’s part, and teachers must be convinced that it is worth the investment. A teacher’s workload may be diminished by means of DBR, which offers teachers well-prepared teaching sequences that they may adapt for their own purposes with a modest amount of effort. In addition, a relatively short teaching sequence like the one introduced in this research report cannot be solely responsible for enhancing students’ motiva-
tion and interest; rather, methods of facilitating the internalisation of students’ regulation of their behaviour and thus optimising their motivation and interest should be built into all the activities in science classes. Simple but significant methods like a teacher’s autonomy-supporting manner of interacting with the students (Reeve & Halusic, 2009), encouraging students to take responsibility for their actions and more generally following the principles of the IBST, should be implemented in all science lessons. Thus the motivation and interest would be supported throughout the whole school year, and site visits could offer a deeper understanding about applications of science to even larger number of students. Challenges for future research-design projects lie in finding suitable means of examining students’ motivational state related to science learning, designing research-based teaching sequences that are easily implementable and adaptable, and educating pre- and in-service teachers to adopt and embrace a way of planning their teaching that supports students’ autonomy, competence, social relatedness, and interest development.

The theoretical background might also be broadened to take into account students’ personal needs and whether their environment supports or endangers students’ active decision-making. In her construction of the life-span model of motivation, Salmela-Aro (2010) describes motivation as a result of four key mechanisms. The first relates to the degree of the fulfilment of personal needs and the environmental factors that can channel adolescents’ trajectories. The second concerns students’ actively making choices and thus influencing the future. The third concerns sharing life goals with others in the social environment, while the fourth involves adjusting their goals and thinking according to feedback received. The first mechanism related to motivation is not especially under an individual’s control, but the other three relate to metacognitive skills that can be made visible to students and practiced by them. Thinking, self-regulation skills, and responsibility belong to extensive competencies that are emphasised in the renewal of the National Core Curriculum for pre-primary and basic education (FNBE, 2012).

From school, and more precisely, the science education point of view, the environment that either supports or inhibits the fulfilment of psychological needs may be partially under teachers’ control by their choice of activities and their style of interaction. In this study, the focus has been in this area, i.e., environmental (teacher and instruction dependent) factors planned to enhance motivation and interest. However, in line with the demand of the IBST (Minner et al., 2010) for students’ responsibility, future designs for science education should not only optimise the environments for facilitating basic needs fulfilment but also also foster the development of students’ skills of goal-setting, monitoring successes or failures and redirecting their activities. These perspectives bring thought-provoking challenges for future research.
References


## Appendices

### Appendix 1 ESIAQ Questionnaire

**EVALUATION OF SCIENCE INQUIRY ACTIVITIES**

**STUDENT NUMBER:** ______

**DATE:** ______

**COUNTRY:** ________________________

**NAME:** ______________________

For each of the following statements dealing with scientific inquiry activities, please indicate how true it is for you, using the following scale: **not at all true (1) … very true (7)**

<table>
<thead>
<tr>
<th>When I engage in science inquiry activity ...</th>
<th>not at all true</th>
<th>somewhat true</th>
<th>very true</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I enjoy the activity very much.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I think I am pretty good at the activity.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I put a lot of effort into the activity.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I did not feel nervous at all while doing the activity</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I believe I had some choice about doing the activity</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I believe the activity has some value for me.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I feel really distant from my peers while doing the activity.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. The activity is fun to do.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. I think I do the activity pretty well, compared to other students.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I didn’t try very hard to do well at the activity.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. I felt very tense while doing the activity.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. I felt like it was not my own choice to do the activity.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I think that doing the activity is useful for my science studies.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. I really doubt that my peers and I would ever be friends through the activity.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>15.</td>
<td>The activity is boring.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>16.</td>
<td>After working at the activity for a while I feel pretty competent.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>17.</td>
<td>I tried very hard on the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>18.</td>
<td>It was important to me to do well at the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>19.</td>
<td>I was very relaxed while doing the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>20.</td>
<td>I didn’t really have a choice about doing the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>21.</td>
<td>I think the activity is important to do because it can help me in learning</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>22.</td>
<td>I feel I could really trust my peers participating in the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>23.</td>
<td>The activity did not hold my attention at all.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>24.</td>
<td>I am satisfied with my performance for the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>25.</td>
<td>I didn’t put much energy into the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>26.</td>
<td>I was anxious while working on the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>27.</td>
<td>I felt like I had to do the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>28.</td>
<td>I would be willing to do similar activities more because they have value for me.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>29.</td>
<td>I’d like to interact with my peers participating in the activity more often.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>30.</td>
<td>I would describe the activity as very interesting.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>31.</td>
<td>I am pretty skilled at the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>32.</td>
<td>I felt pressured while doing the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>33.</td>
<td>I do the activity because I have no other choice.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>34.</td>
<td>I think doing the activity could help me to learn science.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>35.</td>
<td>I feel close to my peers during the activity.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
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<tr>
<td>---</td>
<td>-----------------------------------------------------------------</td>
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<tr>
<td>36.</td>
<td>I think the activity is quite enjoyable.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.</td>
<td>I couldn’t do the activity very well.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38.</td>
<td>I do the activity because I want to do it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39.</td>
<td>I believe that doing the activity could be beneficial for me.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.</td>
<td>I don’t feel like I could really trust my peers who are participating in the activity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41.</td>
<td>When I am doing the activity, I think about how much I am enjoying it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42.</td>
<td>I do the activity because I have to do.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43.</td>
<td>I think the activity is an important activity.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Appendix 2 AMQ Questionnaire**

**ACADEMIC MOTIVATION FOR LEARNING SCIENCE**

**STUDENT NUMBER:** ________

**DATE:** ____________ **COUNTRY:** _______________ **NAME:** _________________________

### WHY DO I LEARN SCIENCE?

Using the scale below, indicate to what extent each of the following items presently corresponds to one of the reasons why you learn science.

For each of the following statements dealing with scientific inquiry activities, please indicate how true it is for you, using the following scale: **not at all true (1) … very true (7)**

<table>
<thead>
<tr>
<th>Why do I learn science?</th>
<th>Does not correspond at all</th>
<th>Corresponds moderately</th>
<th>Corresponds exactly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Because I have the impression that it is expected of me.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. To show myself that I am a good student.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Because I choose to be the kind of person who knows many things as an adult.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Because it’s important to me to learn science.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Because I enjoy the feeling of acquiring knowledge about science.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. For the enjoyment I experience when I grasp a difficult subject in science.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Because it will help me make a better choice regarding my career orientation.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. For the &quot;high&quot; feeling that I experience when I am having discussions with interesting science teachers.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Because studying science allows me to continue to learn about many things that interest me.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Because I think it is good for my personal development.</td>
<td>1 2 3 4 5 6 7</td>
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<tr>
<td>11.</td>
<td>For the pleasure that I experience in knowing more about science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Because I would feel ashamed if I couldn’t discuss with my friends about things concerning science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>I don’t know why I study science, and frankly, I don’t give a damn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>In order to get a more prestigious job later on.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>For the &quot;high&quot; feeling that I experience while reading about various interesting science subjects.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Because science learning allows me to experience a personal satisfaction in my quest for excellence in my studies.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>Because I really like science learning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Because I would feel guilty if I didn’t study science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>Because I’ll get in trouble if I don’t do so.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>For the pleasure I experience when surpassing myself in science studies.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>Honestly, I don’t know, I truly have the impression of wasting my time in studying science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.</td>
<td>I once had good reasons for learning science; however, now I wonder whether I should continue.</td>
<td></td>
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</tr>
<tr>
<td>23.</td>
<td>Because I choose to be the kind of person who knows matters concerning science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>For the satisfaction I feel when I am in the process of accomplishing difficult exercises in science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.</td>
<td>Because I want the teacher to think I’m a good student.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.</td>
<td>For the satisfied feeling I get in finding out new things.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Anni Loukomies

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>27. Because for me, science learning is fun.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>28. I don’t know why I am studying science.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<tr>
<td>29. In order to have a better salary later on.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>6</td>
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Appendix 3 Interview Questions

Semi-structured interview, questions
Guided questions or themes discussed with the students during the interview.

Part 1: Motivation

0. Orientation
Can you please tell me about the site visit and the learning tasks related to it.

1. What was most interesting or motivating in the site visit teaching sequence?
What else was interesting or motivating?

Ask about the following features of the site visit if the student does not mention anything about them.

2. What kinds of possibilities did you have to influence the way things were done during the site visit teaching sequence?
Was it interesting or motivating to have an influence on the way things were done during the site visit teaching sequence?
Did you have possibilities to plan the learning activities?
Did you have an influence on the way the learning tasks were done?
Did you have an influence on choosing the learning tasks?
Did you have an influence on the order the learning tasks were done?
What else were you allowed to decide about?
Was it nice to influence the way things were done during the site visit teaching sequence?

3. What kinds of possibilities to work together with your classmates did you have during the site visit teaching sequence?
Did working together with your classmates increase your motivation or interest towards studying?
Did you feel close to your group members?
Was it nice to work together with the other pupils?
Did you have a possibility to plan the learning activities with the other pupils?

4. Did you feel competent during the learning tasks related to the site visit teaching sequence?

Are you sure you were competent?
Did feeling competent increase your interest or motivation towards studying?
What made you feel yourself competent? Was it your own, your teacher’s or other pupils’ view?)

Did you feel competent during the ICT tasks related to the site visit teaching sequence?
Did you feel your competency was appreciated?
Could you do well some other thing related to the site visit teaching sequence?

5. Can you please tell me about your feeling of interest and enjoyment during the site visit teaching sequence.

Did you feel convenient during the learning tasks related to the site visit teaching sequence?
Did your feeling of interest and enjoyment have an influence on your interest and motivation towards the site visit teaching sequence?
What learning tasks affected your interest most during the site visit teaching sequence?

6. Can you please tell me about the motivating or interesting content or context of the site visit teaching sequence.

7. Overall, what do you think about the site visit teaching sequence?

Part 2: Learning

8. What do you know about products of the site visit company?

Do you know, what materials the products consist of?
Do you know, how are products manufactured from materials? What is the manufacturing process of a product like?
Do you know, what properties the products have?
Do you know, where are the products are used?

9. What do you know about the materials used in the company?
Do you know, what raw materials are used to produce materials the company uses and where these materials come from?
Do you know, how the materials are manufactured from raw materials?
Do you know, what properties these materials have?
Do you know, how are the properties of the materials are analysed?
Do you know, a simple structural mode, that explains a property of the material, describes the structure of each material?

10. What do you know about the occupations in the site visit company?
Do you know, what kind of occupations there are in the site visit company?
Do you know, what kind of education is required for each job?
Do you know, what the people who do the various jobs have to do at work?
Do you know, what kinds of skills/abilities/knowledge/attitudes/ways of thinking are required in each occupation?

11. What do you think about site visit as a way of working?
What do you think about the advance preparation of the site visit?
What do you think about the site visit?
What do you think about studying after the site visit?
What do you think about the site you visited?
How do you assess your own working?
What do you think you have learned during the site visit?

12. Tell us something about the mindmaps you constructed before and after the site visit.
**Appendix 4 Conceptual framework for inquiry science instruction**

Inquiry science instruction, conceptual framework (Minner & al., 2010). Reprinted under permission of John Wiley & Sons.

<table>
<thead>
<tr>
<th>Presence of Science Content</th>
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| · Science as Inquiry  
| · Life Science  
| · Physical Science  
| · Earth and Space Science  
  
<table>
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<tr>
<th>Type of Student Engagement</th>
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| · Students manipulate materials  
| · Students watch scientific phenomena  
| · Students watch a demonstration of scientific phenomena  
| · Students use secondary sources (e.g., reading material, the Internet, discussion, lecture, others’ data)  
  
<table>
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<th>Elements of the Inquiry Domain</th>
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| Instruction emphasizes **Student Responsibility for Learning** when it demonstrates the expectation that students will:  
| Generate investigation question(s); use prior knowledge to inform question(s); consider or predict possible outcomes of the question; explore the reasons question(s) are being asked to determine if they are appropriate for scientific investigation; refine questions so that they can be investigated, discuss questions based on previous study or data collection.  
| It demonstrates the expectation that students will:  
| **Display/express interest, involvement, curiosity, enthusiasm, perseverance, eagerness, focus, concentration, pride (all affective)**  
| Instruction emphasizes **Student Active Thinking** when it demonstrates the expectation that students will:  
| Generate investigation question(s); use prior knowledge to inform question(s); consider or predict possible outcomes of the question; explore the reasons question(s) are being asked to determine if they are appropriate for scientific investigation; refine questions so that they can be investigated, discuss questions based on previous study or data collection.  
| Instruction emphasizes **Student Motivation** when:  
| Alter and refine their approach to gathering, recording, or structuring the data based on information they acquire as they proceed.  
| It demonstrates the expectation that students will:  
| **Display/express interest, involvement, curiosity, enthusiasm, perseverance, eagerness, focus, concentration, pride (all affective)**  

<table>
<thead>
<tr>
<th>Question</th>
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| Decide which question to investigate; seek clarification of the investigation question(s).  
|  
| Design |  
| Identify when and where they need help understanding the design; ensure that they (or the class/group/partner) grasps the design and how to implement it; decide what investigation design to use; ensure that the design addresses the research question.  
|  
| Data |  
| Decide the data organisation strategy; decide what data collection strategy to use and/or how to adapt it; identify if they or others need help collecting or organizing data; seek out clarification and advice when it is needed.  
|  
| Conclusion |  
| Decide what strategies to use to summarize, interpret or explain the data; identify if they or others need help in summarizing, interpreting or explaining; and seek out other relevant information to assist in drawing conclusions.  
|  
| Communication |  
| Decide how to structure their communication; seek advice and suggestions from others about how/what to communicate; provide feedback to others about their communication.  

| Instruction emphasizes **Student Motivation** when:  
| Engage in sound discussion and debate; demonstrate the logic they used to draw conclusions and interpretations; articulate the reasonableness and credibility of others’ work; discuss appropriate communication mechanisms including language, visual aids, technology, etc.; articulate the merits and limitations of their work.  
|