Socialia

DISSERTATIONES
PEDAGOGICAE
SCIENTIARUM
UNIVERSITATIS
TARTUENSIS
5

KATRIN VAINO

A case study approach to effect change of chemistry teacher beliefs for enhancing students' scientific literacy

DISSERTATIONES PEDAGOGICAE SCIENTIARUM
UNIVERSITATIS TARTUENSIS

5

DISSERTATIONES PEDAGOGICAE SCIENTIARUM
UNIVERSITATIS TARTUENSIS
5

KATRIN VAINO

A case study approach to effect change of chemistry teacher beliefs for enhancing students' scientific literacy

UNIVERSITY OF TARTU
PRESS

Science Education Centre, Faculty of Science and Technology, University of Tartu, Estonia

Dissertation is accepted for the commencement of the Degree of Doctor of Philosophy in Science Education on March, 13, 2013 by the Doctoral Committee for awarding doctoral degrees in education, University of Tartu

Supervisors: Professor Jack Holbrook, PhD,

Professor Miia Rannikmäe, PhD
Faculty of Science and Technology, University of Tartu, Estonia

Opponents: Professor Shirley Simon, PhD,
University of London, United Kingdom

Commencement: Room of the Council of the University of Tartu,
Ülikooli St. 18, Tartu, on April, 29, 2013, at 16.00 p. m.

European Union
European Social Fund

Investing in your future

ISSN 1406–9709
ISBN 978–9949–32–252–7 (print)
ISBN 978–9949–32–253–4 (pdf)

University of Tartu Press
www.tyk.ee
Order No 100

TABLE OF CONTENTS

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following original publications which are referenced in the text by their Roman numbers:

I. **Vaino, K.,** Holbrook, J., & Rannikmäe, M. (2013). A case study examining change in teacher beliefs through collaborative action research. *International Journal of Science Education,* 35(1), 1–30.

II. **Vaino, K.**, Holbrook, J., & Rannikmäe, M. (2012). Stimulating students' intrinsic motivation for learning chemistry through the use of context-based learning modules. *Chemistry Education Research and Practice*, 13, 410–419.

III. **Vaino, K.** (2009). Identifying chemistry teachers' beliefs. *Science Education International*, 20(1/2), 32–43.

IV. **Vaino, K.** & Holbrook, J. (2008). Challenging chemistry teacher's beliefs – Towards a paradigm shift. In J. Holbrook, M. Rannikmäe, P. Reiska, & P. Ilsley (Eds.), *The need for a paradigm shift in science education for post-Soviet societies* (103–127). Frankfurt am Main: Peter Lang Verlag.

The author contributed to the publications as follows:

For Paper I: designing the study, formulating the research questions, carring out data collection and analysis, writing the paper as the main author.

For Paper II: designing the study, formulating the research questions, carring out data collection and analysis, writing the paper as the main author.

For Paper III: designing the study, formulating the research questions, carring out data collection and analysis, writing the paper as the main author.

For Paper IV: participating in the creation of the study design**,** working out the instruments of the study, participating in the formulation of the research questions**,** carring out data collection and analysis, writing the paper as the main author**.**

1. INTRODUCTION

Dramatic changes are very much a feature of current developments in science and technology, but major changes are also taking place in society. Science and technology are shaping our everyday life to an unimaginable degree. New insights pervade virtually all areas of our life: in new materials for clothing, in transportation, ways of generating heat and energy, advances in computerisation and mobile technology. Alongside the wealth of positive developments within science and technology, societies are moving in democratic directions and enabling better quality of life. Yet, societies are facing complex challenges linked to overpopulation, pollution, climate change, as well as multitude of local concerns.

The ability to keep abreast of the ever widening range of developments and react reasonably to extensive challenges around us involves acquiring multiple literacies. Amongst these, scientific literacy plays a major role contributing to our ability to make the decisions in our lives and how we contribute to lifelong learning, the world of work and to society as a whole. This is likely to include making wiser health decisions, increased confidence in dealing with science and technology innovations, reducing personal risk to hazards and disasters, as well as better awareness to identify pseudo-scientific information; scientific literacy can also be expected to relate to the economic well-being of a country as this means successfully competing in international markets utilising a top level workforce and strong research support (European Commission, 2004).

Increasingly recognised worldwide is the need to enhance students' scientific literacy and it is considered the main goal of science education in many countries today [American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996; Organisation for Economic Co-operation and Development (OECD), 2009; Eurydice, 2011]. A sufficiently high level of scientific literacy is based today on a premise that it is important for all students no matter their vocation and orientation in life.

At the same time, according to a European Commission report *Science Now: A Renewed Pedagogy for the Future of Europe* (High Level Group on Science Education, 2007), there is, at least in Europe, a serious decline in young people's interest in studying science and mathematics. The concern is that as a consequence of students' poor interest towards learning science and science related careers, this may result in a decline of Europe's long term capacity to innovate and undertake high level research. More attention is considered necessary towards attitudinal and affective components for the development of science cognitive and process skills in enhancing scientific literacy (e.g. OECD, 2006; Holbrook & Rannikmäe, 2009). This suggests that there is a need for a shift in science education from a transmission of knowledge towards more motivational, student-centred models of teaching.

Recognising the importance of enhancing scientific literacy, new approaches, such as context-based, or science-technology-society-based (STS) science education, have been promoted, intended to challenge students' lack of interest in science-related studies, as well as enhancing multi-level scientific literacy (Aikenhead, 2005; Bennett, Lubben, & Hogarth 2007; EURYDICE, 2011). These approaches incorporate students' everyday experiences and highlight contemporary societal issues such as ethical or environmental concerns, and as Gilbert (2006) suggests, develop critical thinking skills and social responsibility. In fact, it is claimed that the STS movement aims to promote "practical utility, human values, and a connectedness with personal and societal issues, all taught from a student-centred orientation" (Aikenhead, 2005, p. 384). Going further and appreciating the value of literacy associated with an interaction of science with technology, the goal of science education can be seen as developing students as responsible future citizens who "creatively utilise sound science knowledge in everyday life, or in a career, solve problems, make decisions and hence improve the quality of life" (Holbrook & Rannikmäe, 1997, p. 15).

In an effort to build students' high levels of scientific literacy, the role of the science teacher is considered a very influential factor in increasing the quality of students' learning and hence the gaining of competences (European Commission, 2007; Osborn & Dillon, 2008). Yet many school reforms have had very little influence on the real classroom practice (Lumpe, Haney, & Czerniak, 2000; Mamlok-Naaman, Hofstein, & Penick, 2007), suggesting that many attempts have followed a top-down principle by which teachers' actual needs, thoughts and beliefs have been neglected. The teacher, as the key figure in every school improvement, has been often seen merely as implementor of ideas emanating from scientists and educators. The expectation is that teachers automatically rethink their own practice, construct new classroom roles, and teach in ways they have never taught before (Darling-Hammond& McLaughlin; 1995).

To overcome the gap between reform expectations and the actual and existing teaching in the classroom, there has been a focus on research over the last two decades which examines an understanding of teacher beliefs underlying teacher behaviour (Bryan, 2012). A wealth of research evidence has shown that teacher beliefs are significant indicators of the behaviours that will be present in the classroom (Cronin-Jones, 1991; Fang, 1996; Haney, Czerniak, & Lumpe, 1996; Pajares, 1992). A number of researchers (Nespor, 1987; Pajares, 1992; Bybee, 1993; Tobin, Tippins, & Gallard, 1994; Haney, Czerniak & Lumpe, 1996; Van Driel, Beijaard, & Verloop, 2001; Levitt, 2002; Woodbury & Gess-Newsome, 2002) have emphasised that a change in teacher beliefs is a precursor to classroom change, playing a critical role in restructuring education. At the same time, teacher beliefs are viewed as major barrier to changes in education due to their adherence to traditional ways (Tobin & McRobbie, 1996). Such beliefs filter teacher's decisions and determine classroom practice (Nespor, 1987). In fact, the slow pace of reform has been attributed to the fundamental characteristic of teacher beliefs that beliefs are stable and highly resistant to change (Haney et al., 1996).

The complexity of teacher beliefs can be viewed from 3 directions (Ajzen, 1991). First of all, the complexity in teacher's attitudes toward any behaviour (an AB factor) will play a crucial role in formulating or changing beliefs. A more social variable, called subjective norms (SN), refers to the impact on beliefs by others deemed influential in some way, and third, a control variable (PBC), relate beliefs to the complexities of both the way internal judgements are accepted and external impacts dealt with.

Noting the complexity and relative stability of teacher beliefs, it is not surprising that teaching approaches geared to "science as a body of knowledge to be taught", are still prevailing in the science classrooms (Bybee, 2000; Smith, 2002; Unal & Apkinar, 2007). In Estonia, where according to a national report as part of an international survey on teaching and learning (Loogma, Ruus, Talts, & Poom-Valickis, 2009), the average Estonian teacher tended to use quite traditional teaching methods and gain little students' support compared to the other participating countries. At the same time, Estonia has introduced the new curriculum for secondary as well as for high school level (Estonian Government, 2011). Although the idea of competence based (science) education had been a factor in the earlier 2002 version (Estonian Government, 2002), the new one focuses more clearly on a constructivist approach, including the development of science process skills and students' self-regulated learning. Hence, the new curriculum (2011) requires beliefs and abilities which teachers, by and large, do not actually possess. Clearly steps are required to initiate changes in science teacher beliefs and practices.

The outcome of different professional development programmes in changing teacher beliefs have been quite varying, in the sense that some studies have shown almost no change, while others have reported success (Bryan, 2012). For example, in the study by Yerrick, Parke, & Nugent (1997), teachers generally did not shift their beliefs about the nature of scientific knowledge, teaching and assessment. However, Luft and Roehrig (2007) and also Fang (1996) in his extensive review on teacher beliefs, have claimed that external factors, such as developmental programmes, can impact beliefs. However, notwithstanding the previous research on teacher beliefs, this area is still poorly understood (Jones & Carter, 2007).

Educational research has illustrated the shortcomings on teachers' classroom practice from the occasional, one-shot workshops (lasting one or two days) (Borko, 2004; Jeanpierre, Oberhauser, & Freeman, 2005; Darling-Hammond, Chung, Andree, Richardson, & Orphanos, 2009; Yezierski and Herrington, 2011). Therefore, new ways of teacher development are needed for eliciting a meaningful change in classroom. According to OECD report (2005):

> Effective professional development is on-going, includes training, practice and feedback, and provides adequate time and follow-up support. Successful programmes involve teachers in learning activities that are similar to ones they will use with their students, and encourage the development of teachers' learning communities. A key strategy involves finding ways for teachers to share their expertise and experience more systematically. There is growing interest in ways to build cumulative knowledge across the profession, for example by strengthening connections between research and practice and encouraging schools to develop as learning organizations. (p.136)

Desimone, Porter, Garet, Yoon, & Birman (2002) have pointed out that notwithstanding the exhaustive number of studies related to the topic of effectiveness of teacher development, few recent studies have begun to examine the relative importance of specific characteristics of professional development; thus, they highlight the need to strengthen the knowledge base on what really "works" in making teacher professional development effective. Similar comments have been made in their review article on teacher professional development by Stolk, Bulte, De Jong, and Pilot (2009): although many studies provide detailed accounts of the effects of their programmes, the way the strategies for professional development were transformed into specific activities within a professional development programme remains unclear. This study sets out to extend our understanding of effective professional development that effected change in teachers' beliefs and instructional practices.

1.1. Focus of the research

This study recognises the need for science teacher change, indicated by developments in the Estonian curriculum, European Commission reports (2004) and research outcomes, to enhance students' scientific literacy. However, facing the seemingly entrenched science teacher beliefs stemming from decades of traditional practices, the current research explored an approach which best allowed an interrelationship with such complex phenomena as teacher beliefs and from this, exploration of existing teaching practices.This study sought to develop, with the support of the teachers involved, ways to guide changes in their beliefs and practices towards an STL approach, seen as important for promoting students' scientific literacy.

From the very outset of the study, chemistry teacher beliefs and practice were recognised as being influenced by, and were part of, a complex social system, such as an existing school culture and the ways how chemistry teachers have been used to work and cooperate, the physical environment including affordances, students and students' background, or macro forces like educational policy including the science curriculum. For this study therefore, innovative ways for supporting chemistry teacher development was sought (opposed to ready-made official programmes), small-scale to induce intimacy and evitable qualitative rather than quantitative in design.

In addressing the issues in science education associated with this study, the research goals are:

I. To support chemistry teachers in modifying beliefs formulated based on more traditional teaching styles to adopt more updated (reform-based) classroom practices. This is through utilising STL approaches, thus promoting more student-centred approaches and raising students' intrinsic motivation towards chemistry learning.

II. To determine and to analyse the change of chemistry teacher beliefs and factors influencing such change through a longitudinal small-scale intervention approach.

Based on the goals, the following research questions are posed:

1) What changes occur in chemistry teachers' beliefs (regarding AB, SN, PBC factors) during the longitudinal study allow adopting scientific and technological literacy (STL) teaching approaches?
2) What aspects of the collaborative action research support changes in chemistry teachers' STL-related beliefs?
3) What changes occur in chemistry teachers' classroom practices during the longitudinal study towards adopting an STL teaching approach?
4) What changes occur in chemistry teachers' classroom practices during the project promoting student's intrinsic motivation measured through students' self-reported indicators of interest, autonomy, competence, relatedness and value perceived during the lesson activities?

The research questions are addressed in the following original publications:

Paper I, building on Paper III and IV, addresses research question 1 and compares project teacher beliefs derived from the study in years I, II, and III and gives an interpretation of the aspects of collaborative action research that supported change in teacher beliefs towards the new approach. The Paper I addresses research question 2 and describes more thoroughly the process of the collaborative action research cycle.

Paper II explores research question 4 and addresses to what extent the changes in teachers' classroom practices were perceived by their students, measured through students' self-reported indicators of interest, autonomy, competence, relatedness and value at the beginning and during the project.

Paper III covers the appropriateness of Ajzen's model of beliefs in the current study and outlines the project teachers' beliefs, including perceived constraints, towards the new teaching approach in the second year of the study.

The earliest paper (Paper IV) explores chemistry teachers' initial beliefs related to a new STL teaching approach, using the Ajzen's (1991) model of beliefs. Teacher beliefs are also juxtaposed and compared with their classroom practices.

Research question 3 is answered in chapter 4.

2. REVIEW OF LITERATURE

2.1. Scientific literacy

The main goal of the current study was to instigate and support change in teacher beliefs and practices towards enhancing students' scientific literacy, latter being seen as a key goal for science education today. Although scientific literacy has been said to be an "ill-defined and diffuse concept" (Laugksch, 2000, p. 71), it appears to underpin the science curriculum standards of many countries (including Estonia) and is the focus of international comparisons of student attainment (e.g. Programme for International Student Assessment (PISA) study).

2.1.1. Interpretations of scientific literacy (SL)

It appears there is no universally accepted definition of scientific literacy (Bybee, 1997). In one of the first attempts to define scientific literacy by Pella, O'Hearn, & Gale (1966, as cited in Laugksch, 2000) scientific literacy is broadly defined as science for effective citizenship. Based on the exhaustive review of almost 100 different papers, they conclude that the scientifically literate person needs an understanding of

(a) interrelationships between science and society;
(b) ethics that underpin the scientist in his work;
(c) nature of science;
(d) difference between science and technology;
(e) basic concepts in science; and
(f) interrelationships of science and the humanities.

While point (e) has tended, in the past, to be stressed by most school curricula, little attention has been paid to the other dimensions. In this sense scientific literacy and school science education have tended to have little in common.

In seeing scientific literacy the same as science literacy, Shen (1975, as cited in Liu, 2009) identified three types of science literacy referring to these as:

(a) practical: possession of the kind of scientific knowledge that can be used to help solve practical problems,
(b) civic: to enable the citizen to become more aware of science and science related issues in order to participate in the democratic processes, and
(c) cultural: knowledge and appreciation of science as a major human achievement and cultural heritage.

The above three types of science literacy tend to suggest that differences in the way scientific literacy is interpreted may be appropriate for different countries and people. But as school science curricula tended to adopt an universality around the world, still little attention was paid to scientific literacy in this direction.

Branscomb's (1981) conceptualisation of scientific literacy, as cited in Laugksch (2000), expanded on Shen's categories by more clearly identifying relevant foci. Each of these scientific literacies could be seen to have a focus in a particular orientation:

(a) methodological science literacy;
(b) professional science literacy;
(c) universal science literacy;
(d) technological science literacy;
(e) amateur science literacy;
(f) journalistic science literacy;
(g) science policy literacy; and
(h) public science policy literacy (Branscomb, 1981).

While this is an expansion, it did not make much impression on school science teaching.

Shamos (1995), while refuting the ability of school science education as currently conceived to promote scientific literacy, proposed a hierarchical model of science literacy identifying three levels:

(a) cultural science literacy: a grasp of certain background information underlying basic communication,
(b) functional science literacy: not only know the science terms, but also be able to converse, read, and write coherently using these terms in non-technical contexts, and
(c) true science literacy: understand the overall scientific enterprise and the major conceptual schemes of science, in addition to specific elements of scientific investigation.

This inspired Bybee (1997) to conceptualise scientific literacy, aiming to be inclusive and taking into account an individual's age, developmental stage, life and educational experiences. He proposes four operational yet hierarchical levels of SL as cited in Holbrook & Rannikmäe (2009):

I. nominal literacy: can recognise scientific terms, but does not have a clear understanding of the meaning;
II. functional literacy: can use scientific and technological vocabulary, but usually this is only out of context as is the case for example in a school test of examination;
III. conceptual and procedural literacy: demonstrates understanding and a relationship between concepts and can use processes with meaning;
IV. multi-dimensional literacy: not only has understanding, but has developed perspectives of science and technology that include the nature of science, the role of science and technology in personal life and society.

Bybee proposed a framework, developed over a lifetime, in which the multi-dimensional level is seen as the highest and the ultimate long term goal for the development of scientific literacy.

Notwithstanding to Bybee's work, the most frequently cited definitions of science literacy tend to be those contained in the *National Science Education Standards* (National Research Council, 1996), the American Association for the Advancement of Science, *Benchmarks for Science Literacy* (AAAS, 1993), or developed by OECD under the PISA framework [*Assessing Scientific, Reading and Mathematical Literacy: A Framework for PISA 2006* (OECD, 2006)]. For the purposes of determining progress in science education across countries, OECD (2006) refers to *scientific literacy* as an individual's:

(a) Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues.
(b) Understanding of the characteristic features of science as a form of human knowledge and inquiry.
(c) Awareness of how science and technology shape our material, intellectual and cultural environments.
(d) Willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen.

These capabilities require students to demonstrate knowledge, cognitive abilities, but also attitudes, values and motivations as they meet and respond to issues of scientific and technological relevance. It is noteworthy to recognise that the definition includes both: knowledge of science (knowledge about the natural world), but also knowledge about science itself, and understanding the nature of science as a human activity and the power and limitations of scientific knowledge. In contrast to the earlier definitions (OECD, 1999; 2000; 2003), the OECD (2006) definition of SL explicitly includes attitudinal aspects of students' responses.

Roth (2007) has criticised the understanding that sees SL as static, which does not correspond to the dynamic nature of the literacies that can be observed in society. He proposes

> ...a dialectical notion of scientific literacy, which makes thematic its nature as a situated, distributed, collective, emergent, indeterminate, and contingent process. It articulates the idea that knowing a (scientific) language is indistinguishable from knowing one's way around the world. As a consequence, the goal of science education can no longer be to make individual students exhibit particular forms of knowledge but to provide them with contexts in which it is more important to deal with, select, and negotiate different forms of expertise and knowledgeability. (p. 377)

Roth and Barton (2004) illuminate the relevance of scientific contexts in students' everyday lives by offering a new vision of scientific literacy linked to social responsibility and community development, e.g. students' SL is developed through the exploring the water quality of neighbourhood involving also the other members of the community with an attempt to improve the situation. By their vision, SL is something that can be characterized in the course of action while using scientific language in authentic contexts.

The definition put forward by Rannimäe, Laius, and Holbrook (2010) and developed under a scientific and technological literacy (STL) framework first initiated by UNESCO's (1993) forum on "Scientific and technological literacy for all", goes even further by stating that scientific and technological literacy is "the ability to utilise sound science knowledge creatively in everyday life by solving problems and making reasoned decisions, involving value judgements and communication skills" (p. 250). In this definition, the creative utilisation of knowledge is highlighted and it recognises that technological literacy cannot be separated from scientific literacy as our world is being increasingly shaped by science and technology, and that these key elements play a role in enabling us to cope with change, pursue development goals, make informed decisions, and expand investment in human development itself (Parkinson, 2003). The given definition suggests that scientific literacy is for all, not only for future scientists. Furthermore, it necessitates relating scientific literacy to an appreciation of the nature of science, personal learning attributes, including attitudes, and the development of social values (Holbrook & Rannikmäe, 2007; Roth, 2007).

2.1.2. STL teaching approach

The last twenty years have seen a number of changes take place in the approach to science teaching, of which one of the most significant has been the development of a wide range of materials which use contexts and applications as starting points for developing understanding of scientific ideas; teaching in this way is often described as adopting a *context-based* or *STS (science–technology–society*) approach (Bennet, Lubben, & Hogarth, 2006). Using social and real-life contexts and practical applications as the starting is seen as a potential way to address the major challenges that science education currently faces: lack of clear purpose, content overload, incoherent learning by students, lack of relevance to students, and lack of transfer of learning to new contexts (Gilbert, 2006). The approach to science, technology, and society education is premised on the belief that science education should include historical, philosophical, cultural, sociological, political, and ethical perspectives (Bybee, 1997; Aikenhead, 2005). As future citizens, students must be able to make decisions requiring an understanding of the interaction of science and technology and its interface with society.

The STL framework, used in the current study, is based on the view that sees enhancing scientific and technological literacy as a step towards developing students' capabilities for life through education (Holbrook & Rannikmäe, 1997; 2009). The STL approach, unlike other approaches to context-based science education, focuses on the broader educational context, rather than the learning of the science ideas that pertain to the context (Parchmann et al., 2006, as cited in Holbrook & Rannikmäe, 2010). The learning is thus in line with the goals of education in general and science education is seen as one of many components in the school educational provision (Holbrook & Rannikmäe, 2010). The learning, stemming from relevant aspects of society, moves beyond conceptual science and concentrates in addition on developing an appreciation of the nature of science while paying attention to the development of personal and social attributes of the overall goals of education (Holbrook & Rannikmäe, 2007). Hence, four goals for science education are emphasised in the STL approach (Holbrook & Rannikmäe, 1997; 2007; 2009):

(a) *Development of individual skills*. Students need to be able to utilise science for improving their own lives and coping with the changes taking place in a technologically developing world. This objective includes the ability to be creative, to exhibit ingenuity, initiative, and perseverance, as well as the ability to communicate orally, in writing and by means of symbols, graphs, tables, charts, etc., to better express scientific ideas in a social context. Emphasis is given to developing positive attitude towards science and science learning which reveals itself as perceived relevance for study by the student. Relevance of the learning is identified as one key aspect of teaching for STL. Additionally, personal skills gained from science teaching should enable students to be more aware of the range of career possibilities that match their aptitude and interests.

(b) *Development of social skills.* Social skills in the current study is defined as the ability to recognise and discuss societal problems and issues and put forward informed options that relate science concepts to economic, environmental, moral/ethical, personal and political considerations. This is seen as very important for STL. Development of social skills includes cooperative or collaborative learning, gaining of social values and the ability to make justifiable socio-scientific decisions in order to enable students to become responsible citizens.

(c) *Development of scientific process skills and the understanding of the nature of science*. The nature of science is promoted as a human endeavour, tentative, empirical, culturally embedded, including human inference, imagination, and involved in creativity**.** This goal is realised by suggesting ways for students to obtain and use such empirical evidence for explanations, problem-solving and decision-making. Solving problems (coming from our everyday life) requires a scientific background and possessing knowledge of scientific methods. It begins from a recognition of the problem and the ability to transform the problem into one that can be answered scientifically. The scientific methods comprise a background in handling process skills, such as observing, hypothesising, planning procedures, experimenting, analysing, interpreting, drawing conclusions, handling equipment, controlling variables, measuring, and calculating.

(d) *Science cognitive learning.* In the current context, knowledge covers a whole range science acquisitions, from simple factual aspects, understanding enabling application of the knowledge, to higher order thinking skills such as analysis, synthesis, evaluation and creative thinking. The terms and scientific procedures are introduced on a "need to know" basis which basically means that teaching-learning activities are designed in a way that students are put in a position they feel the need and see the point of extending their knowledge (Bulte, Westbroek, De Jong, & Pilot, 2006). This is particularly pertinent in cases when social issues are seen as the starting points for science learning, thus allowing personal and social components of learning to play a relevant and motivational role in the enhancement of scientific literacy among students.

The STL approach sees utilising student motivation, especially intrinsic motivation, as a very important step for learning (Holbrook & Rannikmäe, 2009). In the current study, the *Self-Determination Theory* (SDT) (Deci & Ryan, 2002) is seen as a useful theory for conceptualising the teaching approach, as well as for developing STL teaching/learning modules. An explanation amplifying how the SDT was operationalised through STL learning modules and the corresponding teaching approach, is given in Paper II.

2.2. Teacher beliefs

Research into teacher beliefs has gained attention over the last two decades in the science education literature. Researchers have recognised promise in examining and understanding teacher beliefs underlying teacher behaviour as a way to yield meaningful changes to practice (Bryan, 2012). Keys and Bryan (2001) have claimed that almost every aspect of teaching is influenced by the complex web of attitudes and beliefs that teachers hold, including knowledge acquisition and interpretation, defining and selecting instructional tasks, interpreting content that is taught, and choices of assessment. These views are mainly relying on the assumption that beliefs are the best indicators of the decisions individuals make throughout their lives (Rokeach, 1968; Bandura, 1986; Pajares, 1992).

Studies of teacher beliefs are mostly related to classroom practice and the relationship between teacher beliefs and practice has widely been discussed in the context of a broad variety of issues in science education as reviewed by Savasci-Acikalin; (2009):

(a) constructivism (Beck, Czerniak, & Lumpe, 2000; Haney & McArthur, 2002; Haney, Lumpe, & Czerniak, 2003);
(b) inquiry (Luft, 2001; Wallace & Kang, 2004);
(c) curriculum (Cronin-Jones, 1991);
(d) science, technology and society (Lumpe, Haney, & Czerniak, 1998);
(e) reform strands (Haney, Czerniak, & Lumpe, 1996; Roehrig & Kruse, 2005);

(f) nature of science (Lederman & Zeidler, 1987; Gess-Newsome & Lederman, 1995; Lederman, 1999).

Notwithstanding the longevity of research in this area, there is not one consensus definition of beliefs consistently used in the literature (Bryan, 2012). This may ensue from the case that belief as a construct, does not lend itself easily to empirical investigation (Pajares, 1992). However, Pajares admits: "When specific beliefs are carefully operationalised, appropriate methodology chosen, and design thoughtfully constructed, their study becomes viable and rewarding" (ibid, p. 308). Luft and Roehrig (2007) have supplemented this view by stating that those who study beliefs need to clearly articulate the nature of the beliefs that are being examined.

2.2.1. Defining teacher beliefs

Beliefs and knowledge. Although some researchers equate beliefs and knowledge, others see a slight difference, or show a reciprocal character between them. For example, Smith and Siegel (2004) in their literature review on beliefs and knowledge, identified five distinct approaches:

(1) knowledge and beliefs are separate constructs with reciprocal impact;
(2) beliefs are subsumed in the knowledge construct;
(3) knowledge and beliefs are inseparable, as they do not represent separate entities;
(4) the term *belief* is used to identify so called naïve conceptions, and knowledge as based on the scientifically accepted constructs;
(5) they are used interchangeably assuming that the difference will be interpreted within context of the research.

In the current research, beliefs are recognised as reciprocal with, but qualitatively different from, knowledge and as Green (1971) has noted: "the difference seems to lie in the truth condition" (p.69). Similar thought is expressed by Pajares (1992), "Belief is based on evaluation and judgement; knowledge is based on objective fact" (p. 313), adding that beliefs have a more affective and knowledge a more cognitive nature. Pajares acknowledges that it is difficult to think about knowledge without judgement or evaluation that one can hold. Beliefs are also described as "personal constructs" or "propositions considered to be true by the individual" (Luft, Roehrig, Brooks, & Austin, 2003, pp.1–2) or "deeply personal, stable, lie beyond individual control or knowledge, and are usually unaffected by persuasion" (Haney & McArthur, 2002).

Beliefs play an integral role in the body of knowledge one develops. Pajares (1992) suggests that "knowledge and beliefs are inextricably intertwined, but the potent affective, evaluative and episodic nature of beliefs makes them a filter through which new phenomena are interpreted" (p. 325). Beliefs, therefore, influence what knowledge will be acquired and how it will be interpreted.

Nespor (1987) goes even further suggesting that teacher beliefs, built on implicit theories or complex cognitive schema about teaching and learning, are far more influential than knowledge in discerning how individuals frame and organise tasks and problems.

Beliefs and attitudes. Attitude has often been used interchangeably with such terms as interest, value, motivation, and opinion and it is commonly defined as a predisposition to respond positively or negatively toward things, people, places, events, and ideas (Simpson, Koballa, Oliver, & Crawley, 1994). Accepting the notion of positive or negative predispositions, Ernest (1989) added also liking, enjoyment, interest and their opposites under the attitude construct. In the current study, attitudes are seen as a component of a teacher's belief systems, as suggested by Ajzen and Fishbein (1980): beliefs are part of belief systems and attitudes are components of these systems.

2.2.2. Nature of beliefs

According to Nespor (1987), beliefs are psychological constructs having the following characteristics:

(1) do not require a condition of truth,
(2) are value-laden,
(3) are relatively static and not easily changed,
(4) build on existential presumptions,
(5) one may have incompatible beliefs as long as they are not examined against each other,
(6) episodic.

Green (1971) put forward a multidimensional perspective of how beliefs are structured. Green (ibid.) focussed on three different aspects of belief structures and on the evidentiality of beliefs (as suggeted by Cooney, Shealy, & Arvold, 1998):

> First there is the quasi-logical relation between beliefs. They are primary or derivative. Secondly, there are relations between beliefs having to do with their spatial order or their psychological strength. They are central or peripheral. But there is a third dimension. Beliefs are held in clusters, as it were, more or less in isolation from other clusters and protected from any relationship with other sets of beliefs. Each of these characteristics of belief systems has to do not with the content of our beliefs, but with the way we hold them. (pp. 47–48)

Green discussed the notion of beliefs that are in isolation from each other and connected to specific contexts. He also added that isolation may occur when contradictory beliefs are developed in contexts in which beliefs are not explicitly compared, or when beliefs are held from a non-evidential perspective, a perspective immune from rational criticism (Green, 1971). This variability can be associated with the *core* (central) and *peripheral* nature of beliefs (Rokeach, 1986; Pajares, 1992), where core beliefs are often more connected within a system and are more coherent with one another, while peripheral beliefs are not as strongly connected to other beliefs and may be in conflict with one another (Luft & Roehrig, 2007). Therefore, peripheral beliefs are able to be susceptible to reflection and change (Howard, 1987 as cited in Brownlee, Boulton-Lewis, & Purdie, 2002) because other knowledge and beliefs are not dependent on them.

In addition to core, and peripheral beliefs, beliefs may also be *emerging*, in the sense that they are developing and not yet fully formulated by a person (Peterman, 1991), e.g. beliefs coming from teacher development programme or teacher collaboration, where teachers have possibilities to test the viability of new approaches towards classroom practice. This form of beliefs may be quite tentative and therefore vulnerable, as they are influenced by the existing core and peripheral beliefs and also by the teacher's current ability to put the new approach into practice.

Applying the analyses given above to chemistry teaching, it seems quite possible for a teacher, to hold simultaneously two contradictory beliefs: for example, that *inquiry learning is the essence of school chemistry* and second that *students best learn chemistry by taking notes and memorising what is to be learned.* The first belief, *inquiry learning is the essence of school chemistry*, as supposed here, may be peripheral in its nature. It may be derived from "authorities" (Rokeach, 1968), like from educators, teacher trainers, or colleagues who have more updated views on teaching, but it is not yet tested and proven in everyday practice by the teacher. But the second and core belief, has been tested day-by-day and strongly related to the other beliefs, pertaining to how best to assess students and what is the nature of knowledge. Still, if a teacher is introduced and familiarised with a new teaching approach, including teaching methods, students' assessment and/or supporting learning materials, the new set of developing beliefs can be called emerging beliefs which, depending on the circumstances, may, or may not, become core beliefs, in time.

2.2.3. Teacher beliefs and practice

The relationship between teacher beliefs and classroom practice has been widely discussed in the literature. The relationship itself seems to be controversial: some studies (Haney, Czerniak, & Lumpe, 1996; Hashweh, 1996; Beck, Czerniak, & Lumpe, 2000; Roehrig & Kruse, 2002; Haney & McArthur, 2002; Levitt, 2002; Wallace & Kang, 2004) found teaching beliefs have a significant influence on classroom practices, others (Mellado, 1998; Simmons et al., 1999) refute this. Still, it should be noted that the studies conducted by Mellado (1998) and Simmons et al. (1999) explored the beliefs and practices of inexperienced teachers only. Their findings were similar to those of other studies (e.g. Luft & Roehrig, 2007) in sense that pre-service or beginning teachers tended to express reform-based beliefs (lets categorise them as peripheral, derived from authorities like teacher educators or educational literature), but in the real classroom exhibited more traditional teaching behaviours (influenced by core beliefs coming e.g. from their school experiences as students). Traditional beliefs seemed to be consistent with traditional practice while reform-based beliefs might not (Bryan, 2012). There is a danger that reform-based beliefs might be related to the tendency of people to give socially desirable responses.

On the other hand, as many studies with in-service science teachers are based on teacher self-reported data without classroom observations (Haney et al., 1996; Hashweh, 1996; Beck et al., 2000; Hancock & Gallard, 2004), this can be one of the reasons that they have found consistency between teacher beliefs and practice (Savasci-Acikalin, 2009). Hence, we have two types of studies here with different results (consistency between beliefs and practice versus no consistency) which still may be influenced by a similar factor: peripheral nature of expressed beliefs. Also, as noted by Cheung and Ng (2000), the clustering effect (Green, 1971), may explain the varying degrees of incongruity between teachers' beliefs and practices. Unambiguous consistency between beliefs and practice seems hardly believable, but reminds us of the complex nature of beliefs, including their diversity. Rather, there is a need to be agree with Luft and Roehrig (2007) that beliefs and practices are mutually interactive: beliefs influence practice and vice versa.

2.2.4. Changing teacher beliefs

Teacher beliefs are said to be quite resistant to change (Haney et al., 1996), although this conclusion is often based on the results of one-shot programmes (Luft & Roehrig, 2007). It seems quite obvious that the most central beliefs (also called core beliefs) are rarely changed by short term impacts or superficial approaches, as this kind of beliefs are considered by different researchers (e.g. Nespor, 1987; Kagan, 1992) as more resistant to change. Moreover, the existing belief system may act as a filter: more compatible experiences or information may be processed within a belief set, while incompatible experiences may be held to the periphery, filtered, or even rejected (Nespor, 1987; Luft & Roehrig, 2007).

The results of different professional development programmes in changing teacher beliefs have been quite varying, in the sense that some studies have shown almost no change, while others have reported success (Bryan, 2012). For example, in the study by Yerrick, Parke, & Nugent (1997), teachers generally did not shift their beliefs about the nature of scientific knowledge, teaching and assessment. However, Fang (1996) and also Luft and Roehrig (2007), have claimed that external factors, such as developmental programmes, can impact beliefs. Further, it seems that it is more difficult to change beliefs of experienced teachers than of induction teachers as Luft (2001) has found as a result of an in-service programme designed to promote inquiry teaching. This may be related to the complex belief system held by experienced teachers, successfully developed throughout their teaching career, and therefore more resistant to change. Nevertheless, one way or another, the beliefs of teachers seem to be subject to varying degrees of change throughout a teacher's career, considered from a long term perspective (Luft, & Roehrig, 2007).

Although different studies about teacher change, as a result of an intervention, have utilised different contextual factors and even different topics for conducting the study, similar characteristics of successful programmes have stood out. Jones and Carter (2007) in their review article suggested these as:

(1) a consistent philosophy promoted throughout the programme,
(2) educators who maintained and espoused a consistent vision;
(3) context-relevant experiences;
(4) similar learning cohorts; and
(5) personalised programmes.

Bryan (2012), in her review, found sustained contact, mentoring and co-teaching, particularly in the context where the teacher and educator are co-researchers, to be successful in facilitating the revision and refinement of teacher beliefs.

2.2.5. Theory of Planned Behaviour

This study used Ajzen's (1991, 2005) *Theory of Planned Behaviour* (TPB) as a theoretical lens to understand and interpret the participant teachers' belief changes towards the new teaching approach throughout the study. TPB was chosen because it is a widely used and validated theory that relies on belief-based measures to provide comprehensive descriptions needed to understand people's intentions to engage in a given behaviour (Ajzen, 1991; Sadaf, Newby, & Ertmer, 2012). According to Ajzen (ibid.), "intentions are assumed to capture the motivational factors that influence a behaviour that indicates how hard people are willing to try and how much effort they are planning to exert, in order to perform the behaviour" (p. 181).

This theory suggests that attitude towards the behaviour (referred to as the AB factor), the subjective norm (SN) factor and perceived personal control (PBC) factor can predict whether a person will behave in a particular way. The personal variable, attitude towards behaviour (AB), reflects teacher's positive or negative personal beliefs regarding favourable outcomes. The social variable, called subjective norms (SN), refers to teacher's perception of whether or not significant others think this behaviour should be performed; and the last, control variable (PBC) is related to the belief about the extent to which internal (ability, skill, knowledge) and external (opportunities, cooperation, resources) factors exist. *Self-efficacy* is also included into the internal factors as the concept of *perceived behavioural control* itself originates from *Self-efficacy Theory* proposed by Bandura (1977) (see section 2.2.5.1.).

A continuing discussion within the TPB framework, relates to which factor of the three (AB, PBC, SN) is the most powerful in determining one's intention and subsequent action. The qualitative research by Haney and McArthur (2002) found SN components (supporting mentors) to be extremely important in helping prospective teachers implement their beliefs about teaching in line with constructivist approaches. However, in a large-scale survey, Haney, Czerniak, and Lumpe (1996) found SN components made little, if any, contribution towards teachers' intention to implement science reform recommendations. Teachers believed that barriers such as lack of effective staff development opportunities, available resources (negative PBC beliefs) and administrative support (negative SN belief) impeded their ability to implement educational reform. The results indicated that attitude toward the behaviour construct held the greatest influence on Ohio teachers' intention to implement all four curriculum strands of a science reform.

Some studies (e. g. Yerrick, Parke, & Nugent, 1997; Haney & McArthur, 2002), have shown the counterproductive role of negative PBC factors, like a system of strict accountability, or state and national assessment, to the development of teacher beliefs aligned more with reform efforts. In their article, Yerrick et al. (ibid.) but also Bryan (2012) claimed that these external conditions may influence teachers to the point that they simply resist thinking about content and teaching in any other way. Lack of planning and classroom time to cover the content in other studies (e.g. Beck, Czerniack, & Lumpe, 2000) have been shown to be an obstacle for teachers to implement constructivist teaching.

2.2.5.1. Self-efficacy

Bandura defines *self-efficacy* as "beliefs in one's capabilities to organise and execute the courses of action required to produce given attainments" (1997, p. 3). Bandura (1997) indicates that self-efficacy is malleable and can be changed given the appropriate environment. According to Bandura (ibid), there are four major strategies for developing ones self-efficacy: (1) mastery experience; (2) vicarious experience; (3) social persuasion; and (4) physical and emotional states. *Mastery experiences* are the most direct and most powerful sources of information in the development of self-efficacy. Performing a task successfully strengthens our sense of self-efficacy, conversely failing to adequately deal with a task or challenge can undermine and weaken self-efficacy (Bandura, 1994). *Vicarious experiences* are more indirect, and occur when people are witnessing other people successfully completing a task. According to Bandura (1994), "seeing people similar to oneself succeed by sustained effort raises observers' beliefs that they too possess the capabilities master comparable activities to succeed" (p. 72). Ones self-efficacy may be increased also through *social persuasion*: getting verbal encouragement from others helps people overcome self-doubt and instead focus on giving their best effort to the task at hand (ibid.). Our own responses and emotional reactions to situations also play an important role in self-efficacy. Moods, *emotional* and *physical states*, and stress levels can all impact how a person feels about their personal abilities in a particular situation. If the person is excited about the task, self-efficacy increases, anxiety and worry, on the other hand, may result in a decrease in efficacy (ibid.).

2.3. Teacher development

Teacher development is a central issue for educational reform. Curriculum innovations require teachers to be ready (possessing the vision), be able (both having the understanding and ability) and be willing to expend the energy when enacting the change (Shulman & Shulman, 2004). In order to support teacher development as a crucial aspect of any educational reform, new ways for teacher development are sought worldwide.

As with many other terms, there is no consistent understanding for the meaning of teacher development. Although the term *teacher development* has been used interchangeably with *teacher learning*, a distinction between the terms *development* and *learning* has received some attention in the literature (Simon & Campbell, 2012). For example, Fraser, Kennedy, Reid, and Mckinney (2007) have suggested that

> ...teachers' professional learning can be taken to represent the processes that, whether intuitive or deliberate, individual or social, result in specific changes in the professional knowledge, skills, attitudes, beliefs or actions of teachers. Teachers' professional development, on the other hand, is taken to refer to the broader changes that may take place over a longer period of time resulting in qualitative shifts in aspects of teachers' professionalism. (pp. 156–157)

Nevertheless, using *teacher development* interchangeably with *teacher change*, the change that takes place through a process of learning, these can be described in terms of transactions between teacher knowledge, experience and beliefs on the one hand, and their professional actions on the other (Fraser, Kennedy, Reid, & Mckinney, 2007). Emphasising the continuity and life-long learning aspects of teacher learning, the term *continuing professional development* (CPD) has been used in recent years. Kelchtermans (2004), for example, defines CPD as "a learning process resulting from meaningful interaction with the context (both in time and space) and eventually leading to changes in teachers' professional practice (actions) and in their thinking about that practice" (p. 220). This definition as suggested by Tang and Choi (2009), highlights the interactive character of CPD – a "dialogue" between the context and the teacher, self-mediated through interactive processes of interpretation and meaning. According to Day (1999), CPD is defined as "all natural learning experiences and those conscious and planned activities which are intended to be of direct or indirect benefit to the individual, group or school and contribute, to the quality of education in the classroom" (p. 4).

2.3.1. Models of CPD

Much research has been conducted over the years trying to determine the best structure and characteristics for professional development. Kennedy (2005) distinguished nine models of CPD which, in turn, she divided into three distinct groups: *transmissive*, *transitional*, and *transformational* with the transformational models being suggested as most likely to bring about sustained change in education.

The first four models are:

Training model – commonly conducted as off-site, one-day courses that focus on training skills, or giving knowledge, delivered by expert who determines the content while participants are in a passive role; this type of CPD has been often criticised due to its lack of connection to the current classroom context in which participants work.

Award bearing model – is one that relies on the completion of award-bearing programmes of study – usually validated by universities; this external validation can be viewed as a mark of quality assurance, but equally can be viewed as the exercise of control by the validating bodies; this type of CPD has been criticised for being too academic and therefore irrelevant for operational teacher practice.

Deficit model – addressing shortcomings in an individual teacher, this tends to be individually tailored, but may not be good for confidence and is unsupportive of the development of a collective knowledge base within the school.

Cascade model – this is relatively cheap in terms of resources as it involves individual teachers attending “training events” and then cascading or disseminating the information to colleagues. It could therefore be argued that the cascade model supports a technical view of teaching, where skills and knowledge are given priority over attitudes and values; the context in which the knowledge was gained may be missed.

Kennedy (2005) identifies all these models as being underpinned by transmissive views of teacher learning as suggested by Simon and Campbell (2012): These models can serve a purpose in terms of enabling teachers to become more informed, gain new knowledge and skills, but being essentially technical, they are unlikely to result in fundamental changes in pedagogy.

A further three models – the *standards-based model*, the coaching*/mentoring model* and the *community of practice model* – can be considered transitional in the sense that they can support either transmissive, or more transformative conceptions of teacher learning, depending on the nature of the relationship between parties and the level of control they have in this relationship.

Standards based – standards are used to scaffold professional development and to provide a common language, thereby enabling greater dialogue between teachers. Also standards have the potential to narrow conceptions of teaching or, to render it unnecessary for teachers to consider alternative conceptions beyond those promoted by the standards.

Coaching / mentoring can take on a form of expert/novice partnership or of peer-coaching; it allows for those involved to discuss possibilities, beliefs and hopes in a less hierarchical manner. Relationship focuses on confidentiality as opposed to accountability. In order for the coaching/mentoring model of CPD to be successful, participants must have good communication skills.

The community of practice involves more than two people; learning within a community of practice and happens as a result of that community and its interactions, and not merely as a result of planned learning episodes, such as courses (Wenger, 1998). Fundamental to successful CPD within a community of practice is the issue of power – community of practice should create its own understanding of the joint enterprise, therefore allowing the members of that community to exert a certain level of control over the agenda (ibid). "While communities of practice can potentially serve to perpetuate dominant discourses in an uncritical manner, under certain conditions they can also act as powerful sites of transformation, where the sum total of individual knowledge and experience is enhanced significantly through collective endeavour" (Kennedy, 2005, p. 245).

Kennedy (2005) introduced two further models:

Action research is suggested as a clearly transformative model of CPD, where teachers analyse their own practice in order to make changes through the cycle of planning, action, and reflection, strengthening thereby the links between theory and practice. Action research has a greater impact on practice when it is shared in communities of practice; it can act also as a means of supporting "greater participation, relevance and democracy" (Weiner, 2002, p. 3). Action research as a model of CPD has been acknowledged as being successful in allowing teachers to ask critical questions of their practice and has, therefore, clearly significant capacity for transformative practice and professional autonomy (Kennedy, 2005).

A truly *transformative model* is seen by Kennedy (2005) as an effective integration of the range of models described above, together with a real sense of awareness of issues of power, i.e. whose agenda are being addressed through the process. This model includes communities of inquiry, which might be based on partnerships between teachers, academics and other organisations, and which can involve both the context, and the knowledge required, for real and sustainable educational change. Such communities take "inquiry," as opposed to merely "practice", as their unifying feature, thereby asserting a much more proactive and conscious approach than is necessarily the case in communities of practice.

This categorisation and organisation of CPD models, as proposed by Kennedy (2005), suggests increasing capacity for teacher autonomy as one moves from transmission, through transitional to transformative categories.

2.3.2. Other characteristics of CPD

In addition to the nature of the relationship between those involved and the level of power shared, other characteristics for professional development experiences are proposed. These can have a substantial, positive influence on the classroom practice of teachers and on student achievement identified by Birman, Desimone, Garet, and Porter (2000), Garet et al. (2001) and Darling-Hammond et al. (2009) as:

(1) extended duration;
(2) teacher in-depth involvement;
(3) activities organised as a reformed type enterprise, such as a study group, teacher network, mentoring relationship, committee or task force, internship, individual research project, or teacher research centre (in contrast to traditional formats like courses and teacher conferences);
(4) supporting collaboration between teachers;
(5) having a content focus (rather than a very general pedagogical focus) and aligned with curriculum emphasis;
(6) coherence between the programme and teachers' personal goals and needs;
(7) enabling pedagogical issues as being seen to be embedded in the real classroom context.

Wallace and Loughran (2012) put forward a model of teacher learning which highlights both the individual and collective components. Their model suggests that "teachers need the opportunity to engage with authentic activities, participate in rigorous and critical debate within discourse communities, and develop facility with the various tools used in that community" (p. 302). While authentic activities, they suggest, are most often associated with the classroom and the school, it is difficult for teachers to break out of routine teaching. They emphasise the need for the more sophisticated cognitive, cultural and language tools of practice that are often to be found in discourse communities outside the school – e. g. in professional associations, universities and district and central offices, whether in the format of action research, case writing, video club or some other (ibid.).

2.3.3. Teacher development through designing curricular materials

One way to help teachers to adapt to the reform is to encourage and support teachers to design learning materials, aligned with the reform efforts. In such a case, there is more hope that the materials are developed in the light of their own and students' needs, taking also into account the local contexts. Through iterative cycles of design, teachers can learn to engage with curriculum materials and teach more productively (Forbes & Davis, 2008). The mechanism is well explained by Vos (2010):

> The intention is twofold; giving the teachers the role of designer will result in the development of teaching materials which are recognisable by other teachers and closely linked to their belief systems. This will reduce the feeling among teachers of being forced to change their practices, and can avoid incongruence between what is intended and what occurs in classroom practice. Additionally, acting as designers will help teachers to develop their thinking about curriculum materials and empower them to shape their own classroom practice. (pp. 17–18)

Through such design activities, teachers can gain in commitment and ownership with respect to the educational change, thus enabling a substantial innovation regarding change in their knowledge, skills, beliefs, attitudes about teaching, and in getting acquainted with new subject matter (Stolk, Bulte, Jong, & Pilot, 2009).

2.3.4. Teacher development through action research

Action research as a way to improve the current practice of a teacher, but also as an effective means for teacher professional development, has gained more and more attention in education. Although there are a number of different definitions of action research, one of the most comprehensive is offered by McKernan (1996):

> Action research is the reflective process whereby, in a given problem area where one wishes to improve practice or personal understanding, inquiry is carried out by the practitioners – first, to clearly define the problem and secondly to specify a plan for action – including the testing of hypotheses by application of action to the problem. Evaluation is then undertaken to monitor and establish the effectiveness of the action taken. Finally, participants reflect upon, explain developments, and communicate these results to the community of action researchers (p. 5).

Action research, if well designed, seems to satisfy many of the criteria suggested for successful professional development. This notion is amplified further, through 5 key aspects:

Focus on teachers' existing needs and issues embedded in real classroom contexts. Teachers in their every-day practice encounter a variety of practice-related questions and often informally pursue related solutions, alternative perspectives, and new ways of teaching. To more effectively meet the needs of their students, it is necessary for teachers to identify areas in their practice that require modification and further development. If teachers do not typically examine their knowledge about teaching, or question their underlying beliefs about teaching in these ways (Little, 1990; Cochran-Smith & Lytle, 1992), then through action research teachers can become more effective in their practice and find solutions to problems they confront in their everyday lives (Stringer, 2007), or change their practice in ways that fit their unique teaching settings (Price, 2001). Hence, in essence, teacher action research is geared to reflecting on the reality of the profession of teaching.

Empowered control over the agenda. Action research provides an opportunity for the teacher to be a powerful agent of change through investigating his or her own pedagogy, or exploring an issue within their field of education (Cochran-Smith & Lytle, 1999; Brighton, 2009). Burbank & Kauchack (2003, as cited in Kennedy, 2005) argue that action research provides an alternative to the passive role imposed on teachers in traditional models of professional development. They advocate teachers being encouraged to view research as a process, as opposed to merely a product of someone else's endeavours. This type of professional activity presents teachers in a completely new light. Teachers begin to view themselves (but also others) not as "mere technicians who merely apply initiatives handed to them by others" (Kraft, 2002, p. 175), but as reflective, capable teacher-researchers who understand what it means to look at one's practice critically and elicit change when necessary.

Teacher in-depth involvement and extended duration. Critical action research, as defined by Kemmis and McTaggart (1988), requires teachers to engage in a cycle of questioning, planning, reflecting, acting, observing, reflecting, re-planning, and often posing further questions. Engaging in action research can encourage teachers to move beyond common understanding of effective practice to practice that is based on empirical data (Merino & Holmes, 2006). Action research provides a context for teachers to safely investigate all aspects of teaching, including student learning, the curriculum, as well as relationships, school culture, and identity. Studying these aspects of teaching can influence school and, in the wider perspective, educational reform. Based on Kennedy's classification (2005), the duration of common action research projects needs to be regarded as two-three months up to a year or more to elicit real and meaningful changes in practice and become truly transformative in the sense of teacher development. It is even hard to think of action research as short, one-two day enterprises.

Includes both, the individual and collective component of teacher learning and supports teacher collaboration. In addition to the learning process through individual action research projects, the sharing of what one has learned from this process is also an important part of the action research cycle for many practitioners (Cochran-Smith & Lytle, 1999; Brighton, 2009). Results from action research projects are often shared and reported by teachers within the educational community through conferences, workshops, and publications. Collective components of teacher learning are especially empowered when collaborative action research is undertaken. Carr and Kemmis (1986) noted that collaboration is more that just involvement of individuals; it stresses *participation*, a precursor of collaborative reflection, along with being a driving force for further actions. Beyond thinking about one's own thoughts and actions, reflection within collaborative group includes "sharing your own ideas, listening and reacting to someone else's ideas, listening to the reactions of colleagues to your ideas, and trying to integrate these into your thinking" (Zeichner & Liston, 1996, as cited in Tabachnick & Zeichner, 1998, p. 310).

Collaborative action research groups also have the power to challenge and change isolated and typically unexplored beliefs, as well as offer opportunities to explore teachers' conceptions and understanding about teaching and learning and convert them into articulate and research-informed knowledge (Scott & Weeks, 1998). McNiff (1993) has suggested that when teachers begin to share their knowledge and beliefs, they are demonstrating the internal validity of their mental models. Critical peers may or may not accept this knowledge as valid, by discussing and adapting it for themselves. In this way, peers are generating knowledge through a dialogical process within a community of self-reflective practitioners.

The benefits from conducting collaborative action research may be even more enhanced when teachers work together with university educators (e. g. Catelli, 1995; Clift, Veal, Johnson, & Holland, 1990). Collaborative action research can focus on issues that hold interest to both university and school partners. While the teachers bring the perspectives of practice to the research, the university researcher contributes theoretical perspectives which provide ways of critically reflecting upon and transforming practice, thus seeing both sets of perspectives as essential and equal (Aspland, Macpherson, Proudford, & Whitmore, 1996). In this way, the existence of common interests and common goals helps to bridge the often-present gap between educational research and school practice (Raymond & Leinenbach, 2000).

Focus on content and alignment with curriculum emphases. Although action research can take on a variety of forms, as Cochran-Smith and Lytle (1993) have demonstrated, all do not necessarily meet current criterion. For the most part, only those dealing directly with cognitive and emotional aspects of learning and teaching, development of general competencies, or challenges teachers face when teaching students (mainly related to the concrete subject and subject content within the existing or evolving curriculum), are included. Although, one might suggest these are the common themes for most research conducted by teachers, in the current study, the adaptation and development of new curricular materials for chemistry courses was the main reason and focus for conducting the collaborative action research. Hence, the current study additionally sets out to meet this last criterion for successful professional development.

2.3.4.1. Action research process

Different authors concur on the steps for undertaking action research. Most authors refer to a minimum of four stages: (1) planning, (2) acting, (3) observing, and (4) reflecting (e.g. Lewin, 1946, in McKernan, 1996). In this study, further steps were incorporated, similar to those suggested by Glanz (1998):

(a) selecting a focus or a problem worthy of overcoming in one's work setting,
(b) collecting data,
(c) analysing and interpreting the data,
(d) taking action or implementing an intervention,
(e) reflecting on the results of the action, and
(f) modifying one's actions based on those reflections.

Gall, Gall, & Borg, (2007) added a seventh step: reporting the results of the action research study.

Typically, action research is on-going; the end of one cycle signals the beginning of another and more informed cycle of inquiry. Action researchers do not necessarily carry out the stages of their study in any particular order and may return to an earlier stage of the project as their research progresses.

There are several problematic issues and constraints seen as impeding teacher action research in school, the most common of them being a lack of time, inadequate resources, lack of school structural supports, lack of skills or abilities to do effective action research and students' disapproval (McKernan, 1996). The reality may be that teachers, overwhelmed by their routine workload, feel a lack of time and capability for this kind of enterprise, even if motivated towards self-research. For that purpose, involving facilitators for action research, is helpful. Their role in this collaborative action research process is seen by Avgitidou (2009) as follows:

A facilitator should be flexible and sensitive to the context, needs and prerequisites of the collaboration, which requires:

(a) facilitator's documentation, constant analysis of their own and teacher's ideas, feelings and proposals;
(b) many discussions and meetings with the teachers that give opportunities for shared knowledge construction as well as ample time for teachers to describe what goes on and their concerns and practices;
(c) honesty and trust among the members of the team that allows for challenge, doubts, questions, exchange of ideas and proposals; and
(d) appreciation of the fact that who someone is, what s/he thinks and practices, has to be respected and seriously taken into account in order to build collaboration and not impose strategies on the teacher practice. (Avgitidou, 2009)

While not imposing his or her ideas on teachers, the facilitator nevertheless must necessarily advocate particular curricular views. In the worst situation, it is an asymmetrical and one-sided flow of information from facilitator to teachers which may not even influence teacher beliefs nor practice (Fazio, 2005). Thus, the relations of power should be clearly addressed by the facilitator when action research is undertaken. The problematic issues and disagreements may be also an object of on-going discussions. It depends on the general atmosphere of the team whether disagreements are taken as a normal part of collaboration or not. Hence, the role of the facilitator is undoubtedly critical to the functioning of any collaborative group.

3. RESEARCH METHODOLOGY

3.1. Case study approach

This study was conducted using a qualitative approach; more particularly, through a case study methodology. The focus was on providing a detailed description and analysis of five teachers' expressed beliefs, and the combined experience they all shared, in order to identify changes in their beliefs over a three-year period. Moreover, presumed causal links between the project and changes in teacher beliefs were sought, as in-depth case studies conducted in conjunction with large-scale field studies can provide important insights about the processes and mechanisms by which the causes produce their effects (Shavelson & Towne, 2002). In the current study, an interpretive approach is used, which is based on the need to capture the insider's or emic point of view, to clarify the meaning of a phenomenon to both the participant and the researcher (Miles & Huberman, 1994; Merriam, 2009).

The researcher believes that case studies can be used to provide basic information on the complexity of the phenomena and processes that have been little understood, e.g. the mechanism of teacher change. The case study is the "preferred strategy when "how" and "why" questions are being posed, when investigator has no or little control over events, and when the focus is on the contemporary phenomenon within a real-life context", "especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 1994; 2008). Even a single case study can be used to pursue an explanatory, not merely an exploratory or descriptive, purpose (Yin, 1994). The case study approach seemed to be appropriate for the current study as, in addition to the descriptive purposes, causal explanations of project activities on teacher change were sought.

The case is defined as a "phenomenon of some sort occurring in a bounded context" (Miles & Huberman, 1994, p. 25) constituting together a bounded system (Stake, 2005). The most straightforward examples of such "bounded" systems are those where the boundaries have a common sense obviousness, whether it be an individual teacher, a single school, or an innovative programme (Adelman, Jenkins, & Kemmis, 1983, p. 3). The unit of analysis, not a topic of investigation, characterises a case study (Merriam, 2009).

The "unit of analysis" (Miles & Huberman, 1994), in this study is defined as the project, and every teacher is considered a sub-unit of analysis. The "context" is the schools in which the participants worked day-by-day with their students and through which the participants gained their teaching experiences during the study as well as from the past, within the overall educational paradigm.

3.2. Design of research

3.2.1. Selection of participants

Purposeful sampling (Patton, 2002) and the maximum variation principle (Merriam, 2009) were applied in the study in identifying possible participants. The researcher attempted to invite teachers with different views on teaching, from more traditional views towards those more reform-based. Teachers teaching in country as well as town schools were involved. Both of those criteria were applied in order to increase the possibility of a greater range of applicability or transferability of current findings to settings familiar to the potential reader. However, it should be recognised that in sense of teaching experiences, the main group (two teachers left for different reasons) was quite homogeneous, they all had yearlong experiences in teaching chemistry. As the average age within chemistry teachers in Estonia is approaching to 50 years (Estonian Education Information System, 2012), it could be said that even the main group was quite representative in that sense.

The five participants are described in Paper I. The summary table (Table 1) is provided here to give a short background of the teachers. The author's role in the study is also discussed in Paper I and in section 3.4.

Table 1. Participant teachers' background

Participants	School subject taught	Years of experience*	School type**
Anneli	Chemistry	17	Country school
Liina	Chemistry	34	Town school
Marge	Chemistry, mathematics	15	Country school
Kaire	Chemistry	16	Country school
Mari	Chemistry, biology	17	Town school

* When initiating the project
** The classification of schools into country or town school is based on Estonian Ministry of Education and Research (2010)

3.2.2. Description of the setting

All five teachers and their schools belong to the same district in Northern part of Estonia. In all cases, the school type was, gymnasium (equivalent to K-12 education). The number of students ranged in these schools from approximately 500 to 850 during the period study was conducted, which could be considered middle-sized in the context of Estonian school. The students in these schools came from a diverse population, in the sense of differing socio-economic status of the home and academic background, but being quite homogenous by nationality, as overwhelmingly most were Estonians, with some from Estonian-Russian-mixed families, and only very few from Russian families. Only students at the upper secondary level from Liina's school may be considered as academically more advanced in science subjects as, first, her school is situated in the centre of the district (in contrast to the more remote schools), and secondly, the school has a yearlong tradition in teaching advanced courses in science subjects.

In this Northern Estonian district, chemistry teachers had cooperated actively organising student chemistry competitions and teacher activities like joint trips to the institutions and sites related to science, joint meetings for planning and conducting different activities such as workshops and invited guests.

3.2.3. Project activities

Project activities, following Kennedy's (2005) transformative CPD model, are described more thoroughly in Paper I, II, and in Vaino and Holbrook (2011). The summary of activities and the purpose of each are given in Table 2.

Table 2. Project activities

School year	Activity	Purpose
2007/2008 Winter	Introductory seminar session	Introduce participants to and familiarise them with the STL teaching approach (philosophy, structure, and learning goals)
	Adaption and implementation of three STL modules in classrooms of the participant teachers	Familiarise teachers with the new teaching approach involved
2008/2009	Project meeting The start of collaborative action research	Plan activities together, involving discussion and finding solutions to the most urgent concerns and constraints which were related to implementing STL modules in the classroom
	Development of a virtual learning environment in Moodle	Facilitate the communication between participants and sharing the developed resources (including modules)
	Four meetings throughout the school year Implementation of prototype modules Development and implementation of the new STL modules: "Which is better: Blend-a-med or Silverstone?" and "Oxygen: An element of life or death?"	Provide teachers with opportunities to reflect on their STL practices, and with relevant theoretical knowledge (e.g. introducing action research, motivational theories, formative assessment); support teachers in dealing with challenges and constraints related to their STL practices

Table 2. Continuation

School year	Activity	Purpose
2009/2010	Running a workshop within the local chemistry teacher meeting	Dissemination of participants' STL practice and developed modules to other teachers
	Three meetings throughout the school year Implementation of existing modules, development and implementation of the new STL module: "Why make home-made cosmetics?"	Help teachers to deal with challenges and constraints related to their STL practices; gain real ownership of STL teaching
	Running a workshop at a state level chemistry teacher meeting	Dissemination of participants' STL practice and developed modules to other teachers
	Participation in the international conference ICASE 2010 by means of a poster on "Designing, implementing, and evaluating learning modules: Collaborative action research"	Dissemination of participants' STL practice and developed modules to other teachers
2010/2011	Running an independent two days in-service course for chemistry teachers, developed and conducted by participants	Dissemination of participants' STL practices and developed modules to other teachers
	Implementation of existing modules	Help teachers to deal with challenges and constraints related to their STL practice, strengthen the existing positive STL related beliefs and gain real ownership of STL teaching

3.2.4. Module design

The context-based modules, used to guide this study, were specially designed, based on Self-Determination Theory (Deci & Ryan, 2002). The modules set out to capture students' intrinsic motivation through satisfaction of three basic psychological needs (autonomy, competence, and relatedness) and through this build learning thereby enhancing scientific literacy towards responsible citizenry (Paper II). Each module consists of three stages built on the model taken from Holbrook and Rannikmäe (1997).

The first stage is based on an authentic issue (context), starting from an everyday-life scenario seen as familiar to the students' lives acting like a backbone for stimulating the teaching and learning processes that followed. The first step is seen as promoting two attributes:

(1) students' individual interest, necessary for arousing and maintaining their motivation to learn chemistry, and

(2) helping students to see the value of the learning activities; such relevance being also an important factor for intrinsically motivational learning. According to these suggestions, the scenarios are presented in a variety of stimulating ways, often using supporting video clips.

In the second stage, the scientific ideas and problems to be solved, and the associated process skills, personal and social attributes, are incorporated into the teaching. Context-stimulated, but decontextualised, scientific inquiry-based learning is expected to maximise students' personal interest and involvement in their scientific learning process.

In the third stage, the initially put socio-scientific issue is revisited, allowing students to discuss the issue in which they can show that they can transfer and incorporate their newly acquired scientific knowledge alongside other reasoned considerations, such as ethical, environmental, social, political, and economic factors in order to, through argumentation, arrive at a justified socio-scientific decision. The overview of STL modules is given in Table 3.

Table 3. Overview of the STL modules used in the study

Title of the module	**I stage** **Putting forward a scenario**	**II stage** **Inquiry-based problem solving/ Type of inquiry***	**III stage** **Socio-scientific desision making**
Should vegetable oils be used as a fuel?**	A video clip about youngsters who travel around Europe with a van that is powered used vegetable oil	Making and testing the biodiesel in comparison with other fuels/ Open	Decision is made whether and how vegetable oil can be viable as a fuel today
Should we do more for saving monuments?**	A story about famous statues that are corroding; the problem is posed whether it is possible to maintain these	Exploring the factors that influence the corrosion of metals/ Guided	Decision is made on what would be the "best" way for cleaning silver things at home
Alcohol measurement: Could this save somebody's life?	A newspaper-like story about a car accident caused by a drunk driver	Measuring alcohol in a drunk driver's blood by back titration /Structured	A court case (role play) related to the drunk driver is enacted
Which is better: Blend-a-med or Silverstone?	The issue is posed on how to clean safely silver things and whether expensive chemicals are better than those cheap and simple	Cleaning silver jewellery; exploring the factors that influence the process/ Open	Decision is made about the "best" method of cleaning silver
Oxygen: An element of life or death?	TV-news about an accident with cylinders filled with oxygen	Producing oxygen and testing its properties/ Open	Decision is made how people should act in the case of accident
Why make home-made cosmetics?	The issue is posed whether and why one should make cosmetics at home when they are available everywhere	Designing and producing a cosmetic cream/ Guided	Decision is made whet-her and why one should make cosmetics and what are its pros and cons

* Based on Banchi and Bell (2008)
** Prototype modules; adapted from Holbrook and Rannikmäe (1997)

3.3. Data collection

By choosing the instruments, it is important to ensure from their use, it is possible to get answers to the research questions. Nevertheless, the selection depends on the researcher's theoretical orientation as Glesne and Peshkin (1992) have noticed: people tend to choose instruments that are consistent with their worldview. In that sense the selection was influenced by the author's own recognition as a teacher and as a previous district level head of chemistry teachers, that teachers often tend to give "right" answers (what is thought to be "correct" or "plausible") when asked about their teaching methods. This may be the result of different training teachers have experienced, or partly by the demand to report their work and show continuously their "progress," even if there is no progress at all. In order to see beyond teacher's "learned" beliefs (in the current study such beliefs are defined as part of peripheral beliefs) different methods and data sources were used in order to capture their "true" or core beliefs which inevitably have strong influence on a teacher's classroom practice. At the same time, it is recognised, that the existence of peripheral beliefs (including "learned" beliefs) are a result of many processes including past and present teacher practice; they have some rationale, not just being fabrications.

Munby (1982) and Fang (1996) have noted the shortcomings of written self-report responses that may reflect "what should be done," rather than "what is actually done" in practice (as cited in Luft and Roehrig, 2007). Therefore, a number of different data sources, like teacher interviews, classroom observations, data obtained at teacher meetings, and informal comments, were used in order to capture the richness and complexity of teacher beliefs and satisfy the notion expressed by Rokeach (1968, p. 2): "Beliefs must be inferred as best one can, with whatever psychological devices available, from all the things the believer says as well as does".

This study uses a case study approach. According to Yin (1994, p. 13), a case study "copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis". Different authors (Van Maanen, 1988; Strauss & Cobrin, 1990; Yin, 1994) have noted that a case study strategy should not to be equated unambiguously with "qualitative research". Moreover, case studies can be based on any mix of qualitative and quantitative evidence (Yin, 1994). So in this research, where teacher interviews, meetings, conversation, and observation data were supplemented by quantitative, i.e. student questionnaire data, providing us with background information about teacher beliefs and practice.

Five types of data were collected for this study. The purpose for each of them and the timeline indicating when they were used is described in Table 4.

Table 4. Data gathering methods used in this study

Strategy	Timeline 2008 Winter 2009 2010 2011 Spring	Purpose
A semi-structured interview with each teacher		Provide evidence of the teachers' beliefs about teaching chemistry
A semi-structured interview with each teacher		Provide evidence of the teachers' beliefs towards the STL approach
Teacher informal commentaries		Obtain a triangulated view on teacher beliefs towards the STL approach
Teacher meeting data		Obtain a complementary view on teacher beliefs towards the STL approach
Classroom observations		Give indications about teachers' usual teaching practice; interpret teachers' beliefs regarding their practice
Classroom observations		Provide evidence how STL-modules were implemented and adapted in the classroom; interpret teacher's espoused beliefs related to STL approach
Intrinsic motivation questionnaire for students		Provide evidence on the teacher ability to implement a STL approach in the classroom through the students' eyes

3.3.1. The semi-structured interviews on teacher beliefs

The interview questions were developed following the model described by Ajzen and Fishbein (Ajzen, 2005). According to the model, the researcher identified the teachers' salient beliefs, or key perceptions of the consequences (AB), personal support (SN), and controls (PBC) associated with their engagement in a specific teaching behaviour through asking a series of carefully constructed questions. In the first interview, each teacher was asked general questions related to beliefs about teaching chemistry in order to map the initial situation ("starting position") in the teacher beliefs. The three main questions asked have been stated in Paper IV.

Three interview questions were also asked in the second, third, and fourth interview sessions, conducted respectively at the end of the school years I, II, and at the end of the project. These questions focused on the implementation of the STL approach (Paper I, IV).

All interviews lasted approximately one and half hours in order to ensure the interviews were conducted in a friendly atmosphere (Paper IV). The teachers were permitted to digress from the questions and even comment on unrelated matters. All interviews were recorded and transcribed for analysis soon after the data collection.

3.3.2. Teacher informal commentaries

Teachers' informal commentaries were transcribed immediately after each relevant conversation throughout the study in order to obtain feedback from the teachers regarding their experiences with the STL approach and the challenges they confronted.

3.3.3. Teacher meeting data

All meetings were audio recorded and transcribed after each meeting. In addition, indicators of teacher beliefs from teacher commentaries and teacher meeting data were sought alongside the interview data. All three data sources were used for data triangulation in order to capture the "real" beliefs of the teacher.

3.3.4. Classroom observations

These were seen as a complementary component to data collection. Classroom observation aimed to ascertain the extent to which teachers' classroom practices were affected by their beliefs. All observations followed a non-participative format. Each session consisted of 4–5 lessons per one teacher until (based on Strauss & Corbin, 1998), theoretical saturation was reached.

Lessons of one session could take place in such a way that two or three lessons were observed together (basically during the first and last session), or separately on different days (basically during module lessons). As the researcher tried to observe lessons of one module from the outset to the end of the module with the one and the same class, the lessons could occur on different days.

The first session of classroom observations was carried out at the beginning of the study prior to the introduction of STL ideas. The purpose was similar to the first interview when the "starting position" of each teacher was sought. The follow-up sessions were carried out at the end of the first school year, in order to develop an understanding of how STL-modules were implemented and adapted in the classroom and also interpret teacher's stated emerging beliefs related to the STL approach.

When during the second session, the observed lessons covered such modules as "Should vegetable oils be used as a fuel?" (Mari, Liina) or "Alcohol measuring: Could this save somebody's life?" (Kaire, Anneli, Marge), then during the third session, lessons were observed during the modules like "Alcohol measuring: Could this save somebody's life?" (Liina); "Which is better: Blend-a-med or Silverstone?" (Mari, Anneli); "Oxygen – an element of life or death?" (Kaire, Marge).

The last session was carried out at the end of the study in lessons where teachers were purposefully asked not to demonstrate module lessons (modules that were adapted and developed during the project).

The observations of the first and last session covered even more diverse topics than during module lessons originating from the all compulsory chemistry courses, both from the secondary, as well as high school, levels. The purpose of classroom observations was not to explore all aspects of teaching, but rather to understand to what extent lessons were aligned to the philosophy of the STL teaching.

It is recognised that the teaching repertoire depended not only on the teacher, but also on the chemistry topic itself, as the affordances of one topic could be different from another. This chiefly concerns the nature of science and inquiry aspects and science related carrier possibilities. For example, if nature of science aspects are appropriate to introduce through the topic of atomic structure, then it would be quite difficult to carry out experiments and gather data within the same topic. Even the module lessons, although following the same three-stage design and targeting the same learning goals, they have slightly different emphases in addressing learning sub-goals.

Notwithstanding this kind of diversity, it is assumed by the researcher that the "snapshots" from the teacher's practice reflected, by and large, the overall picture of the teacher's teaching repertoire and teaching style in a given stage of the project.

The teacher practices that occurred in the classroom were observed and documented in the format of detailed field notes. Observations focused on the issue how much teacher action in the classroom was attempting to attain the four goals emphasised in STL approach as indicated in chapter II. These four goals: (1) development of individual skills, (2) development of social skills, (3) development of scientific process skills and understanding the nature of science, and (4) science cognitive learning, were checked for operationalisation at the classroom level in the sense of what teacher and students actually do to meet these four goals.

Observation notes were made in four parallel columns: the first was for timeline, the second for descriptive notes of the actual course of the lesson (activities that occurred in the classroom, summaries of teacher's and students' talk in cases where it was meant for the whole class), the third column was meant for the researcher's reflective notes written during and right after the lesson, while the last was used for coding. An example of gathered field-notes is given in Appendix 1.

3.3.5. Student questionnaire

A modified version of the Intrinsic Motivation Inventory (Deci & Ryan, 2007) was used to assess students' interest (enjoyment), their perceived choice (autonomy), competence, relatedness and value in their usual chemistry lessons and in the module context. The purpose here was to provide an insight into how the teacher's practice was perceived by their students in terms of student interest, autonomy, competence, relatedness and how much students valued the lesson activities. The development of the instrument and validation issues, plus data analysis procedure, have been discussed more thoroughly in Paper II. In response to the pre-questionnaire statements, students were asked to give their estimation regarding their last 4–5 chemistry lessons while in the post-questionnaire, regarding the module lessons. During the subsequent school year, after implementing modules with the same students a number of times, the same questionnaire was again implemented to solicit post use of modules.

3.3.6. Researcher diary

As a participant-observer (Patton, 2002, pp. 262–268), the researcher took notes throughout the study. The diary documented the researcher's ongoing reflections over the course of the project, different actions undertaken, conversations with teachers and her own practice as a teacher implementing the STL approach.

3.4. Data analysis

Based on the suggestions by Miles and Huberman (1994) the qualitative data analysis consisted of three procedures: (1) data reduction; (2) data display; (3) conclusion drawing and verification.

3.4.1. Data reduction

Data reduction covered the processes of selecting, focusing, simplifying, abstracting, and transforming the data that appeared in written up field notes, or transcriptions. The data was condensed for the sake of manageability and transformed to address issues of importance.

In the data reduction phase, the mass of qualitative data (interview, teacher meeting records, classroom observation data, researcher notes) was reduced and organised. Segments in the data set responsive to research questions were identified and coded. Codes (Miles and Huberman, 1994) were attached, usually to phrases or sentences, seldom to whole paragraphs. Coded data were then clustered and categorised according to AB, SN, PBC belief factors. Irrelevant data was discarded. The last particularly concerned data from teacher meetings, as teacher conversations sometimes side-tracked and went far beyond education and teaching.

Further data reduction forced the researcher to revisit the raw data and check whether different data under the same general code was consistent and supportive. For this type of data, a-priori codes were used taken from the conceptual framework, e.g. “chemistry is a body of knowledge” (AB belief), but most of them were grounded – generated from the data themselves, e.g. “testing as a main motivator” (AB belief) or “lack of ability to make students learn” (PBC belief). An example of analysed interview trancription is given in Appendix 2. As data collection proceeded, further ways of data reduction was used like writing summaries and memos.

Observation notes were coded after the lesson according to the descriptors given in Table 5 using four categories related to STL goals:

(1) development of individual skills,
(2) development of social skills,
(3) development of scientific process skills and understanding the nature of science,
(4) science cognitive learning.

The initial codes were generated using STL framework (in that sense, they were a-priori codes), but after being tested in practice they were developed into a more workable format. The final list of categories, codes, and descriptors is given in Table 5. During the analysis process, reflections and analytic memos were added. The quantified data were standardised based on the schema: when the descriptor never occurred – 0; occurred once or twice – 1; occurred 3–4 times – 2; occurred 5 and more times – 3. The means of each category were calculated according to each observation stage per teacher (respectively for sessions I, II, III, IV). The purpose of standardising the data was to highlight diversity maintaining the completeness, rather than let repetitive behaviour over-influence the category.

Table 5. Coding sheet for classroom observations

Categories	Codes/Descriptors
Development of individual skills	I1. Students learn how scientific knowledge could improve life standard/are related to society. I2. Teacher takes into account students' perspective and relies on their previous knowledge and real-life experiences. I3. Topics of the lessons help students to acknowledge science related career possibilities. I4. Teacher interacts attentively with students' ideas, actions, problems, attitudes; provides frequent oral or written feedback. I5. Teacher provides students with possibilities to decide about the content and layout to be used to communicate and justify their explanations, conclusions, and decisions. I6. Teacher values and encourages students' curiosity, independent thinking and creativity. I7. Students can decide themselves about the pace and content of the lesson, choose tasks and difficulty level. I8. Students search relevant information from different sources (beyond textbook). I9. Students use a variety of means (models, drawings, graphs, materials, etc.) to represent their ideas, solutions or decisions.
Development of social skills	S1. Students are provided with the possibilities to cooperate and discuss with each other. S2. Students can enact different roles in the group (as a group leader, manager, secretary, etc). S3. Ethical, moral and societal considerations form part of the usual learning process. S4. Students are reflective about their learning; they ask questions or help from the teacher or peers when something is unclear. S5. Students contribute to each other's learning, help each other to understand, gained knowledge is shared amongst the group or class. S6. Students make justified decisions using moral, ethical, economical etc. reasoning when solving socio-scientific problems.
Development of scientific process skills and the nature of science	N1. Scientific knowledge is introduced to students as tentative in nature, based upon evidence and limited in scope (not faithful copies of reality). N2. Scientific knowledge is introduced to students as a creation of human activity, influenced by people's values, opinions and cultural background. N3. Students seek evidence to support their claims and/or to solve problems, empirically as well as theoretically. N4. Students formulate their own questions or hypothesis to be tested. N5. Students plan and conduct their own investigation. N6. Students use tables and graphs to represent their data.
Science cognitive learning	C1. New concepts and topics are introduced to students in a meaningful manner, showing the purpose of the new knowledge. C2. Students explain familiar phenomena and solve everyday life problems using scientific reasoning. C3. The lesson promotes coherent conceptual understanding. C4. Lesson activities promote students' higher-order thinking skills

3.4.2. Data display

Data was displayed by means of matrices divided into AB, PBC, SN, but also positive and negative beliefs. At the start descriptive matrices representing initial chunks of reduced data were used, but as the study advanced, flow-chart and cause-and-effect type matrices were developed. Refined versions of these are presented in Papers I, III and IV.

3.4.3. Conclusion drawing and verification

In the current study, the data collection, reduction and conclusions drawing formed a cyclical and interactive process. The first stages of data coding led to the ideas how to cluster the initial codes and what should be included into the matrix. In filling the matrix, further data reduction was required for better clarity. By clustered codes from interviews, teacher meetings and informal conversation data, "beliefs" indicated in years I, II, and III were compared with each other, looking for patterns of teacher change processes and factors that supported this change, while, at the same time, challenging the initial conclusions towards the raw data and revisiting the memos and summaries. As a result of this exhaustive process, the relationships between different factors (variables) were identified and causal links were proposed. The themes that emerged from the data were related to the Theory of Planned Behaviour (Ajzen, 1991; 2005).

3.5. Trustworthiness of the current research

This research study strives to ensure meaningful qualitative research. There is much debate about what makes for "rigorous" qualitative research. The epistemological standpoint or research paradigm (e.g. positivist, interpretivist) shapes how criteria for "good" research are viewed. Researchers (e.g. Miles & Huberman, 1994; Patton, 2002; Merriam, 2009) have suggested that the traditional evaluation criteria for reliability and validity of the study design and methods used in quantitative research cannot be applied to qualitative studies as they use a different rhetoric and paradigmatic base.

3.5.1. Ensuring credibility

Maxwell (2005) suggested that certain methods and procedures can be essential to the process of ruling out validity threats and increasing the credibility of conclusions. Credibility is about whether the phenomenon has been interpreted appropriately, whether the findings are credible and make sense to the participants, and the readers (Lincoln & Guba, 1985; Miles & Huberman, 1994). While the credibility in quantitative research depends on instrument construction, in qualitative research, "the researcher is the instrument" (Patton, 2002, p. 109). It means that research depends basically on the ability and effort of the researcher.

The current study strives to meet three criteria suggested by Lincoln and Guba (1985) for ensuring credibility: (1) *prolonged engagement and persistent observation*, (2) *triangulation*, (3) *member-checking*.

In order to ensure the credibility, the current study used:

(1) *Lasting engagement* and *persistent observations* over three years to provide a depth of interaction with the teacher participants. The data collection took place over the course of these years and provided the researcher with multiple opportunities to engage with the teachers within the project activities as well as in participants' schools and classrooms.

(2) As a single method can never adequately shed light on a phenomenon, the study used *triangulation* through the use of multiple data collection techniques, including interviews, teacher meetings data, classroom observations, and informal commentaries from the teachers throughout the extended time interval to understand teacher beliefs in-depth. In addition to these data sources, a student questionnaire was used to augment the main data and obtain the indirect measures of teacher beliefs.

(3) *Member checking* in the current study was conducted in a way where only the meaning of raw data was consolidated with the teacher if necessary, not the analytic categories nor conclusions. This technique was used both for interview, teacher meeting, and also for classroom observation data. The researcher either carefully reflected the comment verbatim back to the participant when something was unclear, or directly asked for clarification. Care was taken when developing codes and categories, as well as drawing conclusions, that these were not exposed to a teacher for fear this might lead to *response bias* (Robinson, Shaver, & Wrightsman, 1991) where the person consciously, or subconsciously, gives response that they think the researcher is expecting. Also the person may also believe that they understand the research and are aware of the expected findings, so adapt their responses to suit. This would have led to the distorted image of teacher beliefs.

3.5.2. Ensuring transferability

Transferability refers to the degree to which the results of qualitative research can be generalised or transferred to other contexts or settings (Lincoln & Guba, 1985).

In order to make the results of this study transferable to other settings, a *thick description* (ibid.) of research context, people, activities and other background conditions is given that could influence the course of the project and results of the research. Appendix 1 gives an example of a classroom observation, while Appendix 2 shows an example of the transcription and analysis of an interview, so as provide an in-depth understanding of the study design.

The notion of a "thick description" may contradict with the general research ethics which assumes the maintenance of the confidentiality of the participant teachers, students, and schools. In the Estonian context, even the size of the school with limited other descriptive data may be sufficient to recognise the teacher for a local reader. So, in the current research, a balance between "thick description" and research ethics was sought, as much as possible, to satisfy both views.

3.5.3. Ensuring dependability and confirmability

Reliability is based on an assumption of replicability, but replication in a qualitative study is not likely to yield the same results. The more important question for qualitative research is whether the process of the study is (a) consistent, reasonably stable over time, researchers and methods, whether the results are consistent with the data collected, and whether research has been conducted with reasonable care and (b) show a degree of neutrality or indicate the extent to which the findings of a study are shaped by the respondents and not researcher bias, motivation, or interest, or being at the minimum, explicit about the inevitable biases that exist (Miles & Huberman, 1994).

In this study (a) consistency is shown by the strategies such as *peer examination*, *investigators position,* and *audit trail*. All those three plus *triangulation* have seen as useful strategies ensuring both dependability and confirmability (Lincoln and Cuba, 1985; Merriam, 2009). As the triangulation issue was described and explained in the previous section under discussion on credibility, here the other strategies for ensuring dependability and confirmability will be discussed.

In this study (b) confirmability is shown by *peer examination* ensured by the researcher through discussing the research process and findings with colleagues in the science education field familiar with the topic, whether during the regular doctoral seminars, or within informal conversations. Peer review created an opportunity for the researcher, first, to discuss the evolving design of the study and afterwards, present the preliminary theory derived from the data for reaction. Debriefing with the colleagues is especially important in the process of developing and checking categories for interview, teacher meeting, and informal commentaries data.

Dependability and the investigator's position. The researcher in this study acted as a participant-observer who was the primary focus for data collection and analysis (Merriam, 1998). The researcher had an indeterminable effect on the teachers and students working with and/or being observed. As the researcher played the triple role of facilitator, researcher and teacher in this research, it is appropriate to summarise her experience and reveal beliefs, assumptions and biases related to the field and briefly discuss the implications this might have had for the dependability of the study.

As a chemistry teacher (with sixteen years of teaching experience at the beginning of the study) the researcher had a personal interest in how to teach students in a way they would be perceived as meaningful and relevant to their own lives and thus that chemistry would "touch" them and would "speak" in ways they can understand. To find ways for teaching that would be perceived motivational by students has been her target from the very beginning of her teaching career. After some years, gaining more experience, the author had a possibility to work as a head of the regional chemistry teachers' association. In this role, she had the rewarding possibility to visit other chemistry teachers' lessons and learn from those. At the same time, the author started to gain insight into "how the state of the art in chemistry classroom generally occurs". Some years later, she started to work as a teacher trainer. This experience, including a yearlong communication in a regional level as well as state level chemistry and science teacher community, helped her to develop understanding about the thoughts, beliefs and needs teachers actually may have. The problems that teachers, those younger as well as the more experienced, often perceived were related to the overloaded and context-free chemistry curriculum and the pressure from the centralised examinations (conducted after the 9^{th} and after the 12^{th} grade). This pressure, as the author perceived being held by teachers, was partially conveyed to the students by raising demands and a clear focus of teaching to the examinations, at the same time neglecting the development of other learning goals like general competences.

Partially as a result of this pressure, students had a rather poor attitude towards, and low (intrinsic) motivation for, chemistry learning, evidenced through chemistry teachers' conversations where this was a usual and frequent topic. The statement heard from a colleague, "I just wish they were more motivated!," expressed emotionally and full of tiredness, made the author think about the phenomenon more thoroughly. It seemed that many teachers saw student motivation as something outside their influence or power. At the same time, it was quite difficult to get some teachers, especially those experienced, to rethink their customary teaching practices and make them reconsider methods they used and perceived as ineffective and, as a consequence, to modify their existing teaching.

As a member of this chemistry teacher community and afterwards, as a teacher educator, the researcher often saw the ineffectiveness of traditional in-service courses lasting a day or two. Added together, the hundreds of hours spent in different "schoolings" seemed to have little influence on teachers' existing beliefs and in recognising the need to reflect on classroom behaviour. Many teachers got, maybe, new knowledge from courses, but at the same time, as the new teaching approaches did not pass through the filter of existing beliefs, they continued to teach in their usual way. It was supposedly happening, partially because of poor supporting contextual factors at school and/or because of low self-efficacy in the area, which was, in turn, caused by the fact they still did not get real ownership from taking part in the course.

On the other hand, being in the role of a teacher, it seemed that teacher educators have too often taken a superior position over teachers in telling what "right teaching" ought to be, while at the same time neglecting and underestimating teachers' practical knowledge and experiences in the field. According to curriculum updates, teachers are expected to change their mental schemas from a transmission approach towards a constructivist approach without clear guidelines, models or examples.

With this in mind, the researcher started to think about the ways that would involve teachers more deeply in the learning processes and support more effectively teacher development, leading to the launch of a doctoral study related to the issue. As a teacher and teacher educator, who had spent hundreds of hours in different schoolings, she believed to possess a feeling towards what generally "works" on teachers.

It was recognised by the researcher that personal experiences and beliefs influenced the whole process of conducting the research. As Hammersley and Atkinson (1995) pointed out, eliminating the actual influence of the researcher would have been anyway impossible. In order to minimise this influence, several attempts was made, primarily through self-reflection as well as making notes, analysing the processes and writing memos.

In undertaking the research the interview situations during the first interview sessions were sometimes quite challenging for the researcher, despite similar experiences beforehand. Asking the questions, developing themes without leading the interviewee, or reflecting on answers without judging or starting to argue was sometimes difficult. Sometimes she felt tempted to move beyond her role as researcher to reformer, offering immediately solutions to the emerging problems. After several interviews conducted during the first interview session, especially when listening and transcribing the records, the findings made it possible to learn from these experiences and move towards minimisation of this kind of researcher bias.

The ability to "put herself into the shoes of others", as perceived by the researcher, can be actually both, the strength in that the researcher had similar background knowledge and she was familiar with the educational context, even with the schools in which the participants taught, but it could compromise the interpretation of the situations. There existed the danger of taking everything for granted and thus transferring her own thoughts and beliefs to the participants. So, in order to reduce this kind of danger, the repeated reading of raw data and derived codes, but also the immediate researcher's reflections was helpful, sometimes leading to the correction of initial codes and interpretations. As the researcher was aware of such limitation, the issue was closely scrutinised.

During the teacher meetings, the researcher tried to incorporate two quite opposite roles: first, the role of a facilitator who tried to foster the process of a discussion while trying to minimise influence on the content and who encouraged every teacher to express herself, and secondly, the participant teacher who shared her own ideas and experiences when appropriate. The researcher recognised that holding only a facilitator position in the study meetings, while being at the same time a member of this micro-community with similar experiences and background as the other participants, would have been quite weird. So, the researcher tried, in this situation, not to impose her own thoughts and beliefs on the other teacher, as much as possible.

During the process of transcribing and analysing the data, the researcher still tried to distance herself simply look at what happened and taking a detached view when drawing conclusions and trying to understand the developments within the single teacher and between the teachers. In this process, again, making notes and writing memos were seen as helpful.

Influenced by the researcher's own experiences, where teachers were often underestimated as partners in curriculum initiatives and seen only as adaptors the researcher tried to generate an environment of a *shared-power relationship* in the study team, recognising that everybody had extensive experiences and ideas to share, to be taken into account and developed further. Like the others, the researcher had large doubts when some newly designed module lessons did not succeed as planned. Negotiations in the format of group reflection were then needed for the researcher as much as for other team members. The STL approach was challenging for everybody, including the researcher, who had to develop further her teaching repertoire, enhance self-efficacy in inquiry teaching, and struggle with the fact that there is always too less than desired classroom time to implement the prescribed curriculum.

Making notes and writing memos served also another purpose: it also described how and when a particular piece of data was collected, how categories were derived and how certain decisions were made throughout the study. It created an *audit trail* (Lincoln & Cuba, 1985) seen as important because "we cannot expect others to replicate our account, the best we can do is explain how we arrived at our results" (Dey, 1993, p. 259).

3.5.4. Ensuring authenticity

Authenticity criteria were used to evaluate the quality of the research beyond the methodological dimensions. As Tobin (2006) has pointed out, "educational research with human subjects (teachers) must benefit those who are involved in the study and that researchers have a responsibility to those who agree to be involved that benefits will not be realised only in the future, but will also lead to improvements as the research is enacted" (p. 25). This was explicitly recognised by collectively defining the problems to be addressed, conducting the inquiry and engaging in collective action so as to make a real educational change. In addition, through the dissemination of the project outcomes to the wider chemistry teacher community, it was intended to catalyse the botttom-up curriculum initiatives and challenge the beliefs also of the other teachers.

Furthermore, it is noted that during, and immediately after the study, three of the participants raised, their level of teacher qualification (this kind of ranking in Estonia is based on teacher self-reflection, but also on external evaluation, while the upgrading itself is initiated by the teacher), which may be partially attributed to the teachers' increased self-confidence and self-development as a result of the study. In addition, one of the teachers became a head of the local chemistry teacher association during the study and started to acquire a master degree in biology education.

3.5.5. Ethical protection

Maintaining confidentiality was an important consideration in this study. To maintain the confidentiality of the teachers, students, and schools, pseudonyms have been used throughout the documents and collected data. No specific descriptors were used that could lead readers to identify the particular teacher or school being studied. Upon receiving agreement from the teacher to participate in the study and in order to administer instruments (students' questionnaire, classroom observations) within the school, oral permission from the relevant school authorities (headmaster, head teacher) was sought and obtained. Furthermore, agreement from students was asked in conducting the questionnaires. After informal conversations, the teacher's agreement was asked before transcribing the relevant comments.

4. FINDINGS AND DISCUSSION

4.1. Changes in chemistry teachers' AB, PBC and SN beliefs

Papers I, III, and IV identify the changes in teachers' AB beliefs throughout the project. These findings are summarised in Table 6.

Table 6. Changes in teachers' AB beliefs

Initial beliefs towards chemistry teaching[1]	Beliefs related to STL approach Year I–II	Beliefs related to STL approach Year III
Chemistry should prepare students for life (all)	(+) It is motivating for students as it is related to students' everyday life (all)	(+) Elaboration and strengthening of existing beliefs (all)
Chemistry is a body of knowledge (Mari, Anneli, Kaire)	(+) Changed teacher's role in the classroom (Anneli, Liina, Marge)	
Development of basic skills (Mari, Anneli, Kaire)	(+) Out of the routine teaching (Kaire, Liina, Marge, Mari)	
Hands-on activities as an illustration of theory (Mari, Liina)	(+) It is possible to meet a wide range of learning goals (all)	
Individualised approach (Mari, Marge)		

+ Positive belief with moderate emphasis (teacher is stating the belief ones or twice with no strong emotional reaction)

At the beginning of this study, the participant teachers held different beliefs towards chemistry teaching, from more traditional (e.g. *chemistry is the body of knowledge that should be transferred to students*) towards more reform based and close to the current understandings of scientific literacy (e.g. *chemistry should prepare students for life*).

Generally, the teachers held AB beliefs towards the STL approach that were mainly positive from the outset of the intervention. This is actually not surprising, as e.g. Van Driel, Bulte, and Verloop (2005) showed that teachers in their survey expressed considerable support for a curriculum that pays attention to the context of knowledge.

[1] Although the initial beliefs of Anneli, Kaire, and Liina were not presented in Paper I because of space limits imposed in the article, these findings are drawn in the same way using the same methods of data collection and analysis.

When during the first year, teacher beliefs were more related to students' increased motivation (as a result of using modules with an everyday life focus during the first year of the study) teachers started to realise that *the new approach is a possibility to get out of the routine teaching* (Anneli, Liina, Marge). But also that by the new approach it is possible to meet a wide spectrum of learning goals, e.g. modules increased students' self-reflection (Mari, Anneli), critical thinking, and knowledge retention (Kaire), developed students' understanding of the tentativeness of scientific knowledge (Liina). The third year did not add any remarkable new beliefs related to the module approach. However, it did strengthen their existing positive beliefs towards the STL approach.

A summary of changes in teacher PBC and SN beliefs as determined by teacher interview, meeting records, and informal commentaries, is given in Table 7 (see also Paper IV, Table 1).

Table 7. Changes in teachers' PBC and SN beliefs

Initial beliefs towards chemistry teaching	Beliefs related to STL approach Year I–II	Beliefs related to STL approach Year III
PBC(–): Lack of relevant teaching-learning materials (all)	**PBC(–):** Lack of self-efficacy in module management and student assessment (all)	**PBC(0/+):** Increased self-efficacy related to management of modules and student assessment (all)
PBC(–): Lack of time to cover curriculum and prepare students for state examination (Anneli, Mari, Marge, Liina)	**PBC(– –):** Lack of time to cover curriculum and prepare students for state examination (Anneli, Mari, Marge, Liina)	**PBC(–/+):** Reduced stress to cover curriculum and prepare students for state examination (all)
SN(–): Lack of support from colleagues (Mari, Anneli)	**SN(+):** Support from the project participants and school administration (Mari, Anneli)	**SN(+):** Support from the project participants (Mari, Anneli) and from the other teachers (all).
SN(+): Support from a colleague (Marge) and laboratory assistant (Liina)	**SN(+):** Support from laboratory assistant (Liina, Mari) **SN(–):** Missing laboratory assistant (Anneli)	**SN(+):** Support from laboratory assistant (Liina, Mari) **SN(–):** Missing laboratory assistant (Anneli)

– – Strong negative belief related to the particular issue, belief is stated recurrently and/or with considerable emotional reaction

– Negative belief with moderate emphasis; teacher is stating the belief ones or twice with no strong emotional reaction or, teacher is making inconsistent claims regarding the issue

0 Teacher has the neutral position towards the issue or does not imply to the issue not during interviews, teacher meetings nor informal conversations

\+ Positive belief with moderate emphasis (teacher is stating the belief ones or twice with no strong emotional reaction)

At the beginning of the study the teachers shared the PBC belief related to *lack of time to cover curriculum and prepare students for state examinations*. This belief became even stronger when teachers started to implement STL modules in their classrooms. This finding is very similar to many others (e.g. Beck, Czerniack, & Lumpe, 2000) which have shown that this negative PBC factor may be the main obstacle for teachers to implement more student-centred teaching.

The further the project advanced, the more it was felt by the teachers that coverage of the chemistry curriculum was not as important for the participants as it was at the beginning of the project. Based on data in Paper I, the frequency of complaints about the lack of time showed a tendency to decline as the project advanced. In the third year, the problem was seen by the teachers in the format of "tacit knowledge" (a problem that all teachers shared, but, at the same time, helped each other in not overemphasising the issue).

When starting to implement the STL modules, teachers sometimes found it difficult to manage modules. This included how to put forward the scenario, how to organise particular activities, and especially, how to facilitate the experimental work of students. During the second year, signs of developing self-efficacy beliefs in these areas were established and strengthened even more by the end of the third year.

Alternative ways of student assessment, suggested in the prototype STL modules, were also seen as problematic. Almost all teachers (except Kaire who did not use it) believed it to be too complicated, or too time consuming. During the second stage (following discussions on how to handle assessment issues), the teachers began to use all, or some of the alternative ways of assessment suggested, such as criterion- and observation-based assessment and/or using peer and self-assessment of students. As a consequence, reflections during subsequent meetings and the final interviews showed positive signs of developing beliefs on the use of alternative assessment approaches.

Involvement during the first year met, to some extent, the teachers' need for relevant learning-teaching materials (as teachers were provided with a number of STL modules when the project started). Nevertheless, a need for more was felt (Marge, Mari, Liina, Anneli). This issue was taken as the focus for subsequent collaborative action research (Paper I).

The need for collegial support was expressed by Mari and Anneli at the beginning of the study (Paper IV). Since taking part in the collaborative action research process, they started to appreciate the fact the project enabled them to communicate with other chemistry teachers, share ideas, and through this process, find solution to some of their problems. Both Anneli and Mari started to feel more support from the school administration, after they had introduced their project to colleagues in their schools. After the self-conducted course in year III (Paper I) a new SN factor emerged: positive feedback from participating teachers who attended the in-service course related to the STL ideas promoted and the developed modules disseminated. This seemed to be important for all 5 (Mari, Anneli, Marge, Liina and Kaire).

The lack of a laboratory assistant was perceived as a constraint by Anneli when she started to implement modules more thoroughly in her classroom. This constraint was expressed throughout the project. In support of this, Liina's and afterwards, Mari's laboratory assistant seemed to be important persons supporting the implementation of STL modules in their classrooms.

4.2. Interpreting changes in teacher beliefs

Based on the Paper I, the factors that influenced teacher AB, PBC and SN beliefs were grouped into three focus areas:

- *Focus 1:* There exists a direct link between involvement in the collaborative action research and teacher belief changes.
- *Focus 2*. There is no direct link between the study and individual teacher activities (still, there is some impetus from the collaborative action reseach), beliefs are changed through the use of individual strategies.
- *Focus 3*. Contextual influences on teacher beliefs.

AB beliefs. As indicated in Paper I, during the first year, teachers developed their STL-related AB beliefs basically, through the focus 2 factors, such as using individual strategies when implementing STL modules (focus 1) in the classroom. Those very initial and therefore tentative beliefs gained support by the focus 3 factor, as the new approach was more motivative for students than teachers' previous approach. It was found that students' increased motivation towards learning, established at stage I, played a role in leading teachers towards greater acceptance of the learning goals targeted by the new approach and in the next years even reduced teacher's concern related to curriculum and teaching time constraints (negative PBC beliefs became more neutral or even positive).

Further, teacher AB beliefs were supported by focus 1 factors like group collaboration, especially group reflection, through which the teachers had the possibility to conceptualise, question or justify the teaching approaches used. The reflection and conceptualisation process of the STL approach was reinforced even more from involvement in an in-service course, where the group set out to convince other teachers why it is important and useful to teach in the STL way. Thus, by the end of the study, evidence suggested, through a strong emphasis on focus 1, the group members had strengthened their attitudinal beliefs in the goals of the STL approach through the use of STL modules, through their involvement in collaborative module development and through their experiences in running a successful in-service course for other teachers.

PBC beliefs. Factors that supported the change in teacher PBC beliefs are proposed in the fourth column in Table 1 (Paper I). Negative PBC beliefs are shown, during the first year of this study, to relate to the realisation that the STL approach means adopting new assessment practices, uncertainty of the usefulness of the modules in meeting curriculum requirements and concerns about dealing with the perceived additional time element associated with the STL approach (Paper 1, Table 1, column I).

As seen from the Table 1 (Paper I), change in teachers' negative PBC beliefs towards alternative ways for students' assessment is explained basically by:

- Focus 1 factor as (1) collaborative development of assesment criteria (all), (2) group reflection (Mari), (3) social pressure from the group to implement new assessment practices (Kaire). All those are seen as a further indication of positive SN influences impacting on a change of teacher beliefs.
- Focus 2 factor as (1) teacher's subsequent ability to apply assessment suggestions (all teachers) or (2) making individual adaptions (Kaire); (3) awareness of the wider range of learning goals targeted by the modules (Liina and Anneli).

The decrease of negative PBC beliefs as *lack of time to cover the intended curriculum* and to *prepare students for the state examinations* can be explained basically by focus 1 factor, accrued SN beliefs in face of group support (all). Through group support, the perceived lack of classroom time was mitigated through the realisation that although the problem did not disappear, it became a shared aspect which guided the group to see these as less important in terms of dominating constraints. Moreover, three of the teachers, on beginning to believe in the merits of the STL approach, were motivated to find individual strategies by themselves (focus 2) to overcome the constraint (Marge, Liina, Anneli). In this sense, these findings were very much in line with Cornett's (1990) outcomes, which showed how teachers, through engagement in focus 1 action research, began to understand their focus 2 role as teachers in determining and shaping the implemented curriculum.

It is suggested that the negative PBC belief, lack of self-efficacy related to module management, was overcome, at the focus 2 level, through the iterative and prolonged implementation of modules (all), and at the focus 1 level, through the group reflection on new practices (Anneli, Mari, Kaire, Liina) and further development of new modules (Marge, Liina). The development of new teaching modules at focus 1 level helped all participants to raise their self-efficacy in managing modules at a focus 2 level in the classroom. This activity helped the teachers to make better sense of the STL approach, at the same time strengthening their existing AB beliefs through making teachers more aware of the learning goals and purposes of their planned module.

SN beliefs. The importance of emerging SN beliefs in the process of the project in minimising different constraints and facilitating acceptance of new practices are indicated for all participants (Paper I). For Mari and Anneli, the focus 1, collaborative action research helped to change the explicitly stated, negative SN belief about the need for more collegial support, as they appeared to be quite isolated in their teaching. The collaboration and group support throughout the action research seemed to meet this need, offering numerous ways to communicate, discuss, or question issues troubling their implementation of STL modules, as well as with general problems in teaching chemistry. The positive SN beliefs were especially reinforced for all of the teachers after the teachers collaboratively self-conducted a focus 1 in-service course and received positive feedback from the audience.

The findings from this study strongly support the importance of SN beliefs, especially those associated with the focus 3 reactions by the students, the focus 1 involvement of the teachers in a collaborative enterprise and opportunity of teachers to receive encouraging comments from their peers and as well as from others in their school environment. As at the usual school situation SN components were seen to make little, if any, contribution towards teachers' intention to implement science reform recommendations (Haney et al., 1996) then through collaborative action research and by collaborative support, teachers overcame largely their initial constraints, strengthening thereby teachers intention and subsequent action according to reform efforts.

4.3. Changes in chemistry teachers' classroom practices measured through classroom observations

The scores based on the meaning given in Table 8, were used to determine the standardised data of classroom observation showing the frequency of occurrences of behaviours aligned with the STL approach as shown in Table 9 (the purpose of standardisation is explained in section 3.4.1.). In addition, observation summaries, written after each session, are used to illustrate the results in the Table 9. These classroom observations are more thoroughly described in Vaino, Holbrook, and Rannikmäe (in press).

Table 8. The meaning of scores

The frequency of occurrence	Score
Never	0
Once or twice	1
3–4 times	2
5 and more times	3

Table 9. Changes observed in teachers' classroom practice

Partici-pant	Session number	Development of indi-vidual skills (Mean)	Development of social skills (Mean)	Development of understanding of NOS and science process skills (Mean)	Science cognitive learning (Mean)
Kaire	I	1.1	0.5	0.5	1.3
	II	1.9	1.5	1.0	1.6
	III	2.3	1.8	1.0	2.0
	IV	2.0	1.1	0.5	1.6
Anneli	I	1.4	0.7	0.7	1.7
	II	2.3	2.0	1.0	2.3
	III	2.3	2.3	1.2	2.6
	IV	2.2	1.8	1.0	2.6
Mari	I	1.0	0.8	0.5	1.6
	II	2.1	2.3	1.0	2.7
	III	2.0	2.3	1.2	2.0
	IV	1.8	1.7	0.9	2.0
Marge	I	1.7	1.5	0.5	2.0
	II	2.4	2.7	1.2	2.7
	III	2.2	2.3	1.2	2.6
	IV	2.4	1.8	1.0	2.7
Liina	I	2.0	1.7	0.8	2.0
	II	2.2	2.5	1.7	2.3
	III	2.3	2.2	1.3	2.7
	IV	2.3	1.7	1.2	2.3

Initial practices. Based on the first observations (session I), Kaire and Mari used quite traditional and direct teaching methods where note taking was usually followed by workbook exercises. However, Marge and especially Liina, used more interactive and student-centred approaches through small group work formats when solving problems empirically or based on the secondary sources where real-life connections with chemistry content were often made, e.g. Marge started to teach reaction stoichiometry from making a dough. Anneli tried to integrate both, direct teaching with strong teacher emphasis and more student-centred approach, e.g. through guided inquiry.

Practices identified during session II. As seen from the Table 9, there is a pedagogical shift from the first phase (teachers' previous practice) to the second when the teachers started to implement the STL modules in their classroom. While implementing STL modules, change took place in all categories (development of individual skills, development of social skills, development of understanding of nature of science and science process skills and science cognitive learning), and by every teacher. Still, as all participants had classroom behaviour that recognised students' perspective and previous knowledge already from the beginning of the study, there was no change or if only, then little change in its frequency. The same tendency (high scores from the beginning of the study) existed within science cognitive learning domain, too: all teachers struggled for better understanding of chemistry of their students helping them to build coherent mental schema. When starting to implement the STL modules, they unquestionably continued to meet the same goal.

Within session II, changes were more evident in the extent the teachers involved every-day life aspects into their teaching, e. g. during the second stage, students became more introduced how scientific knowledge are related to society and students had to explain every-day-life phenomena or solve every-day life related problems. If students posed inquiry questions or made predictions once (Liina) or not at all (all the others) at the beginning of the study, then during the second session of observations, this kind of activity but also planning and conducting an experiment and representing data in tabular or graphical format, was included into the design of the lessons by all of the teachers.

Practices identified during session III. During the third session when module lessons were observed again, teachers' mean scores according to every category remained basically to the same level, exept by Kaire. Kaire, whose changes during the second session had been relatively modest, had moved further for the third session when she demonstarted more STL elements in her teaching than before and therefore increased substantially the mean score in all categories. Based on the made field notes (during 2^{nd} and 3^{rd} session), teachers generally followed the prescribed design of STL modules and by and large according to STL philosophy. During the first session only Kaire almost omitted formative assessment possibilities and in place of some group activities used direct teaching and asked closed questions rather than those demanding divergent thinking. In all other cases, when changes were made, then not substantial, e.g. changing initial scenario (Marge) or changing slightly group work format (Anneli, Liina), still following the STL philosophy. The change was evidenced by increased amount of student-centred activities like student-driven inquiries, group discussions, presentations or searching information from different sources, not only from textbook.

Practices identified during session IV. During the IV session, teachers' scores in every category decreased comparing to the module lessons (2^{nd} and 3^{rd} sessions). If to think that STL modules the teachers implemented in their classrooms were specially designed to meet the learning goals highlighted by the STL approach (development of students' individual skills, social skills, understanding of nature of science and science process skills and science cognitive learning), then it is quite natural that the scores of the second and third session were not met during the last session when teachers implemented their own design. Still, the mean scores remained higher than during the first session by all teachers and in every category. Based on the last observations, if not following exactly the same, three-stage design like STL modules, the teachers tried to integrate STL elements into their every-day teaching, e.g. making frequent connections between chemistry content and every-day life aspects (all teachers) and solving problems relevant to students' lifes, plus involving social and ethical aspects to the learning (all teachers) which led to the justified socio-scientific decision making (Liina and Anneli). Moreover, more open formats of students' inquiry were evidenced by Anneli, Marge, Liina, and Mari during the last session compared to the first where highly structured investigations were prevailing in the classrooms amongst the group.

4.4. Changes in chemistry teacher classroom practice measured through students' self-reported indicators (interest, autonomy, competence, relatedness and value) perceived during lesson activities

The results of the student questionnaire are presented in the Table 10 (Paper II).

Table 10 shows that in general, students' motivation after the implementation of the first module was higher in every subscale and these changes were statistically significant. The biggest, average, change in motivation took place in relatedness and interest subscale and the smallest in value subscale. Additionally, the means were higher in all subscales according to every teacher. Nevertheless, students of Mari did not show significant change in the autonomy subscale and students of Liina in the competence subscale. According to student responses, students found the module approach to be intrinsically more motivational than their usual chemistry learning, as measured by all used subscales. It was especially evident in their changed feeling of relatedness and perceived interest in the module approach.

Table 10. Means and mean changes in subscales of the questionnaire in total and according to the teacher (Paper II)

Subscale (No of items)		No of students	Teacher					
			Kaire N=106	**Anneli** N=62	**Mari** N=48	**Marge** N=130	**Liina** N=74	**Total** N=416
Interest (4)	Mean (SD)	Pre	4,25 (1,17)	4,80 (1,25)	4,65 (1,24)	4,68 (1,19)	4,66 (1,39)	4,56 (1,23)
		Post[1]	5,40 (1,29)	5,44 (1,38)	5,28 (1,04)	5,23 (1,22)	5,14 (1,17)	5,30 (1,21)
	Paired t-test: Mean change (SD)		**1,15****** (1,43)	**0,64****** (1,06)	**0,63**** (1,24)	**0,55**** (1,07)	**0,48**** (1,08)	**0,74****** (1,22)
Autonomy (3)	Mean (SD)	Pre	3,55 (1,25)	4,00 (1,18)	4,24 (1,34)	4,20 (1,35)	4,24 (1,46)	3,98 (1,33)
		Post[1]	4,58 (1,38)	4,65 (1,21)	4,60 (1,34)	4,61 (1,28)	4,68 (1,40)	4,61 (1,32)
	Paired t-test: Mean change (SD)		**1,03****** (1,84)	**0,65****** (1,09)	0,38 (1,58)	**0,41**** (1,26)	**0,44**** (0,95)	**0,63****** (1,30)
Competence (5)	Mean (SD)	Pre	4,23 (1,17)	4,37 (1,23)	4,14 (1,24)	4,45 (1,16)	4,99 (1,27)	4,43 (1,22)
		Post[1]	5,00 (1,04)	4,96 (0,98)	4,84 (1,27)	5,06 (0,92)	5,13 (1,10)	5,01 (1,14)
	Paired t-test: Mean change (SD)		**0,77****** (1,29)	**0,59**** (1,18)	**0,70**** (1,32)	**0,61****** (1,06)	0,14 (1,17)	**0,58****** (1,20)
Relatedness (3)	Mean (SD)	Pre	4,05 (1,18)	3,95 (1,18)	3,95 (1,37)	4,47 (1,17)	4,15 (1,30)	4,17 (1,22)
		Post[1]	5,08 (1,28)	4,82 (1,13)	4,78 (0,95)	5,11 (0,95)	4,99 (1,13)	5,01 (1,14)
	Paired t-test: Mean change (SD)		**1,03****** (1,43)	**0,87****** (1,36)	**0,84**** (1,44)	**0,64****** (1,12)	**0,84****** (1,25)	**0,84****** (1,33)
Value (6)	Mean (SD)	Pre	4,49 (1,19)	4,78 (1,25)	4,67 (1,27)	4,87 (1,02)	4,82 (1,38)	4,72 (1,19)
		Post[1]	5,04 (1,26)	5,20 (1,15)	5,21 (1,02)	5,25 (0,87)	5,18 (1,00)	5,17 (1,08)
	Paired t-test: Mean change (SD)		**0,55****** (1,24)	**0,42*** (1,24)	**0,54*** (1,09)	**0,38****** (1,01)	**0,36*** (0,92)	**0,45****** (1,17)

*p<0,05, **p<0,01,***p<0,001, [1] Pre-test scores are subtracted from post[1]-test scores.

Table 11 shows the results gained from students after multiple use of context-based modules in the next school year. Post[2]-questionnaire data, gathered after the 3rd (4th) module, compared with the data gathered after the implementation of the first module on all subscales, showed the change was positive. However, significant differences existed only in autonomy (mean change 1.01, $p < 0.001$) and relatedness subscale (mean change 0.60, $p < 0.01$).

Table 11. Paired samples t-test on differences between post[2] – and post[1] -questionnaire scores (N=105)

	Post[1] Mean (SD)	**Post[2] Mean (SD)**	**Paired differences:** Mean change (SD)
Interest	5.73 (0.99)	5.94 (0.81)	0.21 (1.10)
Autonomy	4.93 (1.22)	5.95 (0.81)	**1.02***** (1.38)
Competence	5.11 (0.96)	5.14 (0.92)	0.03 (1.33)
Relatedness	5.23 (1.20)	5.85 (0.57)	**0.63***** (1.10)
Value	5.36 (0.97)	5.66 (0.66)	0.30 (1.16)

***p<0.001, post[1]-test score is subtracted from post[2]-test score

Students' motivation if not significantly raised compared to the first encounter, then at least it was maintained after multiple implementations of modules. It is suggested that it happened basically due to the especially designed learning modules using three-stage design geared to enhance students' intrinsic motivation. Moreover, it proves the teachers' ability to stimulate students' intrinsic motivation through five components which may be related to the fact that during the second year, through the collaborative action research, teachers started to develop modules themselves and through iterative use and reflection increased their self-efficacy in the STL approach.

One-way Analysis of Variance with post hoc Scheffe multiple comparisons indicated the following:

Before the intervention, statistically significant differences existed between teacher related students' responses, within the autonomy subscale related to Kaire and Marge, and Kaire and Liina [$F(4,416) = 4.35$, $p<0.01$] and within the competence subscale between teachers Kaire and Liina, and Anneli and Liina [$F(4,415) = 4.17$, $p<0.01$].

After implementation of the first module and after multiple use of modules, students' mean scores (teacher related) in every motivation subscale did not differ significantly.

Although there is a possibility, that students from different schools could be differently motivated, notwithstanding the particular teacher, it is still suggested that questionnaire responses are compatible with the findings based on classroom observations. Students of teachers who exhibited a more traditional teaching style at the beginning of the project (Kaire and Mari), showed relatively lower motivational indicators in learning chemistry. This was more significantly expressed in the category of autonomy and competence perceived by their students. On the other hand, Marge and Liina, who exhibited more updated teaching practices from the beginning, resulted in higher student motivational indicators, measured by almost every sub-category.

4.5. Changes in chemistry teachers' beliefs and practices

Based on the given findings from

- teacher interviews, commentaries and meeting records,
- classroom observations,
- student questionnaires,

all teachers made substantial shifts, both in their beliefs and their practice during the study. This finding was also supported by the results of students' motivational indicators which increased significantly when teachers started to use the STL modules in their classrooms.

Although the "starting position" in beliefs and practices was not the same for all the teachers, they developed their beliefs and practices towards ways more congruent with an STL approach. Liina and Marge, who had relatively reform-based AB beliefs and practices beforehand, held few constraints towards implementing the new approach. On the other hand, Kaire and Mari, who initially had more traditional beliefs and practices, needed to overcome more perceived constraints, but still succeeded in substantially reducing the amount and extent of these and became less traditional in their beliefs and practice. As data indicated, Anneli was somewhere in the middle of this continuum.

It was noticeable that various factors had different influences on the teachers. While social factors, in the sense of group support and the feeling of good social relations, were more important for Mari and Anneli, the process of creating learning materials (still collaboratively) was more valued by Marge and Liina. Kaire was the exception here in that at the beginning of the study, she, unlike the others, did not perceive problems related to student assessment, or a lack of classroom time when using the STL module approach. On the contrary, she only recognised these problems when she started to implement the new approaches more seriously. However, through the collaboration and additional classroom experiences, she found ways to reduce the constraints and raise her self-efficacy (PBC beliefs) related to the new approach.

Martin and Hand (2009) have found that it took at least three years in order to change the classroom practice of an experienced teacher from a traditional approach to a more student-centred orientation. Yip (2001) supports the same notion claiming that experienced teachers are reluctant to give up their pedagogical strategies. In this study, where teachers were involved intensely to the collaborative action research, they were able to change their classroom practices substantially even during the first year of the study. Still, the formation and evolving of beliefs specifically relevant to an STL approach took more time and this process is on-going (Paper I). In that sense, the current study supports the outcomes of Luft (2001) who suggested that first, experienced teachers tend to change their practice and, as a result of their experiences, change their teaching beliefs. Nevertheless, in the current study, beliefs and practices are seen as mutually interactive: beliefs influence practice and vice versa (Richardson, 1996; Luft & Roehrig, 2007).

Findings show that students' reactions to the module approach helped to strengthen teachers' positive AB beliefs (Paper I, II). At the same time, through perceived group support (positive SN beliefs), the teachers were influenced to modify their existing teaching practices (ibid.).

Bandura (1977) suggested that self-efficacy can be enhanced by:

- experiencing success of mastery,
- vicarious experience,
- affective states, and
- social persuasion.

The participants in this study had the opportunity to be involved in many of such experiences. Throughout the project, the teachers had repeated experiences to apply the STL modules in their classroom and gain success in mastery (e. g. recognising that modules are motivational for students and meet a wide range of learning goals). Although experiencing limiting factors like low self-efficacy in module management and alternative ways of assessment (negative PBC's), which in the worst situation, impede the teacher's intention to implement the STL approach, through a collaborative critical examination of constraints and through the development of new STL modules, teachers increased their self-efficacy in these areas. Each teacher had also possibilities to reflect on their experiences with the others, observe the positive outcomes of others (vicarious experiences), encourage each other and being encouraged by other chemistry teachers during the self-conducted, in-service course (verbal and social persuasion), and finally experiencing a positive feedback from the others with respect to affective factors.

It was found that a teacher may hold, simultaneously, contradictory beliefs. For example, when teaching module lessons Mari believed that it is important to support student-centred ways of learning and when teaching other lessons used direct teaching with emphasis on recall and training basic skills (Paper IV). This may be explained by Green's (1971) notion that beliefs are held in clusters, more or less in isolation from other clusters and protected from any relationship with other sets of beliefs. But in the case of an existing belief being challenged iteratively through new experiences, this kind of isolation may be weakened. The weakening of distinct clusters was evidenced in the current study by both,

(1) developing positive beliefs towards the STL approach stated by all teachers, and

(2) classroom observations, when teachers started to integrate the STL approach into their customary teaching practice, above and beyond the specially designed STL modules (IV session of observations).

The findings reinforce the claim that new beliefs must be challenged iteratively through practice (Scott & Weeks, 1998; Mansour, 2009) if substantial changes in teachers' beliefs and practice are expected. This, evidenced by the findings, showed that teachers, through iterative teaching and reflecting on how they taught modules, reduced their negative PBC beliefs. Also these strengthened their positive AB beliefs towards the new approach, because, through this process as stated by McNiff (1993), it was possible to test the internal validity of the teacher's mental models.

This study set out to elicit a sustained change in chemistry teachers' beliefs and practice towards the new approach. Ajzen and Cote (2008) claimed that the more positive the attitude, and perceived social norms together with positive perceived control beliefs (including the self-efficacy), the greater the intention will be for the individual to perform the behaviour in question. The perceived social support alongside the increased positive control beliefs such as self-efficacy towards the new approach in turn increases the likelihood of repeating successful performances in the future (Bandura, 1997; Ajzen, 2005). Hence, it is suggested that this study supports Ajzen and Cote claim.

The study demonstrated also that in addition to the attitudinal beliefs which is often a case when teacher beliefs are studied, subjective norm and perceived control beliefs are a valuable source that are able to shed additional light to such complex phenomenon as teacher beliefs. Although Ajzen's (1991, 2005) model of three belief factors (AB, SN, and PBC) has been often used in quantitative studies within and outside educational research, only very few studies have implemented this framework for exploring change in teacher beliefs. There exists almost no longitudinal studies using Ajzen's model for qualitative data analysis. Therefore, the current study shows the Theory of Planned Behaviour (1991) to be a viable tool for analysing and interpreting chemistry teacher beliefs throughout this longitudinal study. Even when paying attention to all three belief factors, and noting the core and peripheral nature of beliefs *(*as is shown in Paper IV), insufficient evidence is obtained by eliciting teacher beliefs only by teacher interview or even worse, only by questionnaire. The essential beliefs towards the new approach were stated by the teachers also during the meetings and informal conversations (see Paper I). The triangulation of many sources of different data undertaken in this study throughout the extended time interval, were taken to be extremely important in an attempt to capture "as best one can, with whatever psychological devices available, from all the things the believer says as well as do" (Rokeach, 1968, p. 2). The triangulation was seen as crucial in compiling as holistic picture of changes as possible. And it is clear that the involvement of the teachers in collaborative action research, as a further source of evidence showed that interfering negative perceived behavioural and subjective norm beliefs could be meaningfully addressed.

5. CONCLUSIONS AND IMPLICATIONS

5.1. Conclusions

In undertaking this study on changes in teacher beliefs and practices towards an STL approach, through collaborative action research, four research questions were addressed:

1. *What changes occur in chemistry teachers' beliefs (regarding AB, SN, PBC factors) during the longitudinal study allow adopting the STL teaching approaches?*

Throughout the three-year project, teachers:

- Developed and elaborated their mainly positive AB beliefs, such as the "new approach is motivating for students"; "by modules is possible to meet the wide range of learning goals", etc. while confronting their substantial constraints.
- Tackled mainly negative PBC beliefs, such as lack of self-efficacy in module management and student assessment, lack of time to cover curriculum and prepare students for state examination, and few negative SN beliefs such as lack of collegial support. Here the evidence supports the formation of teachers' positive PBC beliefs (e.g. increased self-efficacy towards implementing the STL approach in the classroom, including how to assess students).
- Gained positive SN beliefs (e.g. support from the other participants) in place of negative or missing ones, although the extent, pace, and nature varied, depending on the teacher's individuality.

2. *What aspects of the collaborative action research support changes in chemistry teachers' STL-related beliefs?*

The close cooperation through the format of collaborative action research, especially group reflections, perceived collegial support, and dissemination of the modules to the wider audience turned out to be an effective approach for changing of teacher beliefs and encouraging teachers to implement new instructional practices.

The major role, eliciting change in teacher initial AB, PBC, as well as in SN beliefs, is considered to be the addition of new positive SN beliefs (support from the group, positive group norms towards STL approach, approval from the other teachers) while strengthened AB beliefs (e.g. "modules are motivating for students", "by modules is possible to meet wide range of learning goals") helped to overcome, in some cases, the initially perceived negative PBC beliefs (e.g. "assessment system is difficult to comprehend"). Further strengthening of

SN beliefs is shown through involving teachers in handling effective in-service provisions for other teachers that are intended to impact on participant's AB and PBC beliefs.

3. *What changes occur in chemistry teachers' classroom practices during the longitudinal study towards adopting an STL teaching approach*?

In addition to change in the teacher beliefs, changes occurred in

- their classroom practice: when involved to the study, all teachers started to implement practices, more relevant to a STL approach; this was especially evident during the module lessons specially designed to meet the learning goals of a STL approach;
- teachers started to integrate STL elements, such as using an inquiry approach and relating to every-day life and social aspects in their customary teaching practice.

4. What changes occur in chemistry teachers' classroom practices during the study promoting student's intrinsic motivation, measured through students' self-reported indicators of interest, autonomy, competence, relatedness and value perceived during the lesson activities?

This study shows that changes that happened in the chemistry teachers' classroom practices were also perceived by their students.

Based on the study findings, students' responses:

- were significantly higher in all five indicators of intrinsic motivation related to the lessons based on the modules compared to their previous chemistry lessons;
- increased and maintained, based on these five indicators, through using the modules taught by every teacher.

5.2. Implications

Although limited in its scope, the current study provides insights and implications with respect to future research in science education and science teacher education.

I. Based on the current study, it is suggested that future research exploring teacher beliefs should use a range of instruments (in place of a single measure) to capture the complexity of teacher beliefs. As seen from the current study attempting to be holistic in nature, the data coming from different sources (interview, teacher meeting, commentaries, classroom observations) helped to complement and interpret beliefs coming from all four sources. Relying only on a single instrument could give an incomplete and poor picture of teacher beliefs.

II. The results of this longitudinal intervention have shown the viability of Ajzen's model for interpreting change in teacher beliefs. Therefore, this model is suggested for wider use in qualitative educational studies.

III. Future studies should pay more attention to the distinction between core and peripheral nature of beliefs and provide further insights into how the true core beliefs of teachers could be successfully changed, especially if they are strongly held towards, e.g. teaching as knowledge transmission.

IV. Future teacher in-service education, needs to consider six strategies to support effectively professional development of experienced teachers leading to the sustained change in their beliefs and practice. These are:
    (1) providing teachers with innovative learning materials with opportunities to practice them in the classroom over a prolonged period of time to experience mastery;
    (2) organising the design of innovative learning materials by teachers themselves;
    (3) addressing the existing (especially when negative) beliefs related to the new practices as a target for collaborative action research;
    (4) providing teachers with frequent possibilities of individual and group reflections on their on-going practices as the useful sources of vicarious learning, social persuasion and positive emotions;
    (5) in the format of collaborative action research increase teachers' control over the agenda; and
    (6) providing teachers with opportunities to introduce their innovative practices and the results of their action research projects to the wider audience whether in the format of teacher conferences, teacher journals or at least within teacher meetings in order to gain the real ownership in innovative practices and empower teachers as professionals and the crucial agents of educational reforms.

V. Based on the model of successful teacher development in the current study, the preparation of facilitators who initiate and support those projects, who mediate the underpinnings of STL approach without dictating the agenda for teachers, becomes crucial. Clearly the role of facilitator should be conceptualised beforehand.

APPENDICES

Appendix 1. Example of an observation record

Description of the physical environment:
There is four rows of long benches in the classroom with 24 students from 11^{th} grade (11 boys and 13 girls). The front benches are more densely occupied with students than the back half. I sit at the back of the classroom but can see the whole classroom very well. Student posters are fixed to the walls of the classroom. Other student-made artefacts, like inquiry reports, books, etc. are exposed on a free table on the front left of the classroom, adjacent to the teacher's computer and data projector.

Date: 07.02.2011

Time	Descriptive notes	Reflective notes	Codes
8.55	Bell rings, teacher enters the classroom: "Good morning, let's start the lesson!" The students stand, say "hello", and sit down.		
	Teacher starts the lesson by asking the following question to the class: "If you could choose, which apple you would eat: peeled or not and why?"	Teacher is trying to connect a new topic with the students' everyday life.	I2
	Teacher waits for student responses. Two girls in the front give hesitant responses suggesting a peeled apple would be better.	Interesting start, but where is she heading?	
	Teacher: "More suggestions?" One boy adds something about pesticides and toxicity. His neighbour says that the peel is made from plastic, that's why he does not like them. The others start laughing.	Students seem to be quite restrained which may be due to my presence as it is the first observation with this class or perhaps it is just because it is Monday morning?	I4
	A boy: "Is it really a plastic?" Teacher: "What do you think?"	Teacher patiently waits for answers.	
9.00	One girl in the middle of the class: "It is more like wax or something..."		
	Teacher: "OK, now another question: why flowers smell or... why ladies use perfumes, sorry, not only ladies... What would be the purpose of this?	Students seem to warm up and get more excited.	I4
	A boy in the back: "To ATTRACT! (laugh).	Interesting; will the teacher will draw a connection with biology?	
	An answer is heard from the girl behind him: "That one can express one's personality."	Good idea to use essential oils; it can't leave anybody indifferent when sniffing!	
	Teacher: "Here are samples of some essential oils; you can sniff them in turn and think which smell best suits your personality. Or choose your best attractant!" (laugh). Teacher gives the sample box to the students on the first bench.	Here the teacher goes very nicely over the subject content.	

	Teacher: "Well, I think I have already made you think what would be behind my questions. Actually, our topic today is about esters, which is another class of organic compounds. So, I hope you would like to know more about the compounds what are responsible for a good smell or a protective layer on plants. Now I suggest group work where you will investigate this topic more thoroughly.		C1
9.05	Right now you will get a worksheet, where instructions are given on what to do. I would emphasise that everybody is responsible for his or her work, as you will introduce after 15–20 minutes, your topic to the others.	Teacher gives here concrete guidelines, this is probably a jigsaw-type of group work	C3*
	Students start to compile groups according to the colour given on the work sheet, etc.	It seems they have experienced this approach many times before as it goes so smoothly.	S1

* Based on the given worksheet students were asked, among other tasks, to relate the properties of esters with their structure and field of applications.

Appendix 2. Example of an interview transcription and the preliminary analysis

Date**:** 15.01.2008

	Transcript	Preliminary codes	Reflective notes
1	K (K=Interviewer): So, now it seems to work.		
2	M: Should I talk using my normal voice or louder, so that you can hear it afterwards?		Recording seems to still influence her somewhat.
3	K: Yes, of course, don't let yourself be disturbed at all!		
4	K: So, may I now ask the first question?		
5	M: Bring it on! (laughing)		
6	K: What do you think, what would be the best way to teach chemistry?		
7	M: You mean, what I am actually doing and I feel that YES! in this point I succeed or (..) you mean what I consider as ideal?	Clarification of the question When succeeding Consider as ideal	Here M. is pointing that there is a gap between real and ideal teaching, which is, probably valid for every teacher (?)
8	K: Both of them, just say what you like.		
9	M: OK, I think(.) school chemistry has a lot to do with preparing students for their future life (...)	Preparing students for life	
10	K: You mean for their career or more generally?		There was a long pause after her previous statement, I tried to encourage her to talk further. Was my question here leading too much?
11	M: I mean more like giving them not only relevant knowledge, but also different skills like communication skills, safety working, decision-making and so on (.) If they see that chemistry constitutes a little bit more than only formulas and equations (..), that chemistry is all around us (..) However, I try to draw examples from everyday life to make chemistry more digestible for students, at least as well as I can(.) (tiredly) Sometimes, for some topics, I don't see myself why it has to be taught at all (.) and then it is already difficult to explain to students why they should learn it, etc.	Giving not only knowledge Communication skills Safety working Not only formulas All around is chemistry Everyday life examples Digestible for students At least as well I can Why teach/learn some topics at all	As it seems, she knew exactly what to say and my question was only to fill the gap (maybe even unnecessary) Statement related to the relevance of chemistry was said with noticeable emphasis; it seems to be important for her. Still, the last point refers here again to the gap between the real and ideal,existence of some constraints.

REFERENCES

Adelman, C., Kemmis, S., & Jenkins, D. (1980). Rethinking the case study: Notes from the second Cambridge conference. In H. Simons (Ed.), *Towards a science of the singular* (pp. 45–61). Centre for Applied Research in Education, University of East Anglia.

Aikenhead, G. S. (2005). Research into STS science education. *Educación Química*, 16, 384– 397.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50, 179–211.

Ajzen, I. (2005). *Attitudes, personality and behaviour* (2nd ed.). New York: Open University Press.

Ajzen, I., & Cote, N.G. (2008). Attitudes and the prediction of behavior. In W. D. Crano & R. Prislin (Eds.), *Attitudes and attitude change*. New York: Psychology Press.

Ajzen, I. & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs: Prentice-Hall.

American Association for the Advancement of Science (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Aspland, T., Macpherson, I., Proudford, C., & Whitmore, L. (1996). Critical collaborative action research as a means of curriculum inquiry and empowerment. *Educational Action Research*, 4(1), 93–104.

Avgitidou, S. (2009). Participation, roles and processes in a collaborative action research project: A reflexive account of the facilitator. *Educational Action Research,* 17(4), 585–600.

Banchi, H. & Bell, R. (2008). The many levels of inquiry. *Science and Children,* 46(2), 26–29.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191–215.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs: Prentice Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior, 4* (pp. 71–81). New York: Academic Press.

Beck, J., Czerniak, C. M., & Lumpe, A. T. (2000). An exploratory study of teachers' belief regarding the implementation of constructivism in their classrooms. *Journal of Science Teacher Education,* 11(4), 323–343.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education,* 91(3), 347–370.

Birman, B. F., Desimone, L., Garet, M. S., & Porter, A. C. (2000). Designing professional development that works. *Educational Leadership*, 57(8), 28–33.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8).

Brighton, C. (2009). Embarking on action research. *Educational Leadership,* 66(5), 40–44.

Brownlee, J., Boulton-Lewis, G., & Purdie, N. (2002). Core beliefs about knowing and peripheral beliefs about learning: Developing a wholistic conceptualization of

epistemological beliefs. *Australian Journal of Educational & Developmental Psychology*, 2, 1–16.
Bryan, L. A. (2012). Research on science teacher beliefs. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 479–495). Dortrecht: Springer.
Bulte, A. M. W., Westbroek, H. B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education,* 28, 1063–1086.
Burbank, M. D. & Kauchak, D. (2003). An alternative model for professional development: Investigations into effective collaboration. *Teaching and Teacher Education*, 19, 499–514.
Bybee, R. W. (1993). Leadership, responsibility, and reform in science education. *Science Educator,* 2, 1–9.
Bybee R. W. (1997). Towards an understanding of scientific literacy. In: W. Graber & C. Bolte. (Eds.), *Scientific literacy. An international symposium*. Kiel: IPN.
Bybee, R. W. (2000). Teaching science as inquiry. In J. Minstrell & E. H. Van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 20–46). Washington: American Association for the Advancement of Science.
Carr, W. & S. Kemmis. 1986. *Becoming critical: Education, knowledge, and action research.* Philadelphia: Falmer Press.
Catelli, L. A. (1995). Action research and collaborative inquiry in a school-university partnership. *Action in Teacher Education*, 26, 25–38.
Cheung, D., & Ng, P. H. (2000). Science teachers' beliefs about curriculum design. *Research in Science Education, 30*(4), 357–375.
Clift, R., Veal, M. L., Johnson, M., & Holland, P. (1990). Restructuring teacher education through collaborative action research. *Journal of Teacher Education,* 41(2), 52–62.
Cochran-Smith, M. & Lytle, S. L. (1992). Communities for teacher research: Fringe or forefront. *American Journal of Education,* 100(3), 298–324.
Cochran-Smith, M. & Lytle, S. (1999). The teacher research movement: A decade later. *Educational Researcher,* 28(7), 15–25.
Cooney, T. J., Shealy, B. E., & Arvold, B. (1998). Conceptualizing belief structures of preservice secondary mathematics teachers. *Journal for Research in Mathematics Education*, 29, 306–333.
Cornett, J.W. (1990). Utilizing action research in graduate curriculum courses. *Theory Into Practice*, 29, 185–195.
Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235–250.
Darling-Hammond, L., Chung Wei, R., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Dallas: National Staff Development Council.
Darling-Hammond, L. & McLaughlin, M. W. (1995). Policies that support professional development in an era of reform. *Phi Delta Kappan*, 76(8). Retrieved November, 2012 from
http://www.oest.oas.org/iten/documentos/Investigacion/randd-engaged-darling.pdf
Day, C. (1999). *Developing Teachers: The challenges of lifelong learning*. London: Falmer Press.

Deci, E. L. & Ryan, R. (Eds.). (2002). *Handbook of self-determination research*. Rochester: University of Rochester Press.
Deci E. L. & Ryan R. M. (2007). *SDT: Questionnaires: Intrinsic Motivation Inventory (IMI).* Retrieved October, 2009, from http://www.psych.rochester.edu/SDT/measures/intrins.html
Desimone, L., Porter, A., Garet, M., Yoon, K. S., & Birman, B. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis,* 24(81), 81–112.
Dey, I. (1993). *Qualitative Data Analysis*: *A User-Friendly Guide for Social Scientists*. London: Routledge. Retrieved December, 2012 from http://www.drapuig.info/files/Qualitative_data_analysis.pdf
Ernest, P. (1989). The knowledge, beliefs and attitudes of the mathematics teacher: A model. *Journal of Education for Teaching,* 15(1), 13–33.
Estonian Government. (2002). *Põhikooli ja gümnaasiumi riiklik õppekava (National curriculum for basic schools and upper secondary schools).* Regulation of the Government of the Republic of Estonia, No 56.
Estonian Government. (2011). *Põhikooli ja gümnaasiumi riiklik õppekava (National curriculum for basic schools and upper secondary schools).* Regulation of the Government of the Republic of Estonia, RT I, 14. 01. 2011, No 2.
Estonian Ministry of Education and Research. (2010). Õppeasutuste ja õppurite kohta käiv statistika. (Statistics about the schools and students.) Retrieved January, 2013 from http://www.hm.ee/index.php?048055
Estonian Education Information System. (2012). Teachers and educators. Retrieved January, 2013.
European Commission. (2004). *Europe needs more scientists: Report by the high level group on increasing human resources for science and technology*. Brussels: European Commission.
European Commission. (2007). *Science education now: A renewed pedagogy for the future of Europe*. Brussels: European Commission. Retrieved March, 2010 from http://ec.europa.eu/research/science-society/
Eurydice. (2011). *Science education in Europe: National policies, practices and research*. Brussels: EURYDICE. http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf
Fang, Z. (1996). A review of research on teacher beliefs and practice. *Educational Research,* 38(1), 47–65.
Fazio, X. (2005). *Exploring teacher views of scientific inquiry and the nature of science: A collaborative action research project.* PhD diss., University of Toronto.
Forbes, C. T. & Davis, E. A. (2008). The development of preservice elementary teachers' curricular role identity for science teaching. *Science Education*, 92(5), 909–940.
Fraser, C., Kennedy, A., Reid, L., & Mckinney, S. (2007). Teachers' continuing professional development: Contested concepts, understandings and models. *Journal of In-Service Education*, 33(2), 153–169.
Gall, M., Gall, P., & Borg, W. (2007). *Educational research: An introduction.* Boston: Pearson Education.
Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4).

Gess-Newsome, J. & Lederman, N. G. (1995). Biology teachers' perceptions of subject matter structure and its relationship to classroom practice. *Journal of Research in Science Teaching,* 32(3), 301–325.

Gilbert J. K. (2006). On the nature of "context" in chemical education. *International Journal of Science Education,* 28(9)**,** 957–976.

Glanz, J. (1998). *Action research: An educational leader's guide to school improvement*. Norwood: Christopher-Gordon.

Glesne, C. & Peshkin, A. (1992). *Becoming qualitative researchers: An introduction*. New York: Longman Publishing Group.

Green, T. (1971). *The activities of teaching*. New York: McGraw-Hill.

Hammersley, M. & Atkinson, P. (1995). *Ethnography: Principles in practice* (2nd ed.). London: Routledge.

Hancock, E. S. & Gallard, A. J. (2004). Preservice science teachers' beliefs about teaching and learning: The influence of K-12 field experiences. *Journal of Science Teacher Education,* 15(4), 281–291.

Haney, J., Czerniak, C. M., & Lumpe, A. T. (1996). Teacher beliefs and intentions regarding the implementation of science education reform strands. *Journal of Research in Science Teaching*, 33(9), 971–993.

Haney, J. J., Lumpe, A. T., & Czerniak, C. M. (2003). Constructivist beliefs about the science classroom learning environment: Perspectives from teachers, administrators, parents, community members, and students. *School Science and Mathematics,* 103(8), 366–377.

Haney, J. J. & McArthur, J. (2002). Four case studies of prospective science teachers' beliefs concerning constructivist teaching practices. *Science Education,* 86, 783–802.

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching,* 33(1), 47–63.

High Level Group on Science Education. (2007). *Science Now: A renewed pedagogy for the future of Europe.* Brussels: European Union.

Holbrook, J. & Rannikmäe, M. (Eds.) (1997). *Supplementary teaching materials: Promoting scientific and technological literacy*. Tartu: ICASE.

Holbrook, J. & Rannikmäe, M. (2007). Nature of science education for enhancing scientific literacy. *International Journal of Science Education*, 29(11), 1347–1362.

Holbrook, J. & Rannikmäe, M. (2009). The meaning of scientific literacy. *International Journal of Environmental and Science Education*, 4(3), 275–288.

Holbrook, J. & Rannikmäe, M. (2010). Contextualisation, de-contextualisation, re-contextualisation – A science teaching approach to enhance meaningful learning for scientific literacy. In I. Eilks & B. Ralle (Eds.), *Contemporary science education* (pp. 69–82). Aachen: Shaker Verlag.

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching*, 42(6), 668–690.

Jones, M. G. & Carter, G. (2007). Science teacher attitudes and beliefs. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 1067–1104). Mahwah: Lawrence Erlbaum Associates.

Kagan, D. M. (1992). Implications of research on teacher belief. *Educational Psychologist,* 27(1), 65–90.

Kelchtermans, G. (2004). CPD for professional renewal: Moving beyond knowledge for practice. In C. Day & J. Sachs (Eds.), *International handbook on the continuing* *professional development of teachers* (pp. 217–237). Maidenhead: Open University Press.

Kemmis, S. & McTaggart, R. (1988). *The action research reader* (3rd ed.). Geelong: Deakin University Press.

Kennedy, A. (2005). Models of continuing professional development: A framework for analysis. *Journal of In-Service Education*, 31 (2), 235–250.

Keys, C. W. & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, 38(6), 631–645.

Kraft, N. P. (2002). Teacher research as a way to engage in critical reflection: A case study. *Reflective Practice,* 3(2), 175–189.

Laugksch, R. (2000). Scientific literacy: a conceptual overview. *Science Education*, 84, 71–94.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching,* 36(8), 916–929.

Lederman, N. G. & Zeidler, D. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education,* 71(5), 721–734.

Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education,* 86(1), 1–22.

Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic Inquiry*. Newbury Park: Sage Publications.

Little, J. W. (1990). The persistence of privacy: Autonomy and initiative in teachers' professional relations. *Teachers College Record,* 91(4), 509–536.

Loogma, K., Ruus, V.-R.,Talts, L., & Poom-Valickis, K. (2009). *Õpetaja professionaalsus ning tõhusama õpetamis- ja õppimiskeskkonna loomine* (Teacher professionalism: Creating effective learning and teaching environments). Retrieved April, 2010 from http://www.hm.ee/index.php?048181

Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education,* 23(5), 517–534.

Luft, J. A. & Roehrig, G. H. (2007). Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview. *Electronic Journal of Science Education, 11*(2), 38–63.

Luft, J., Roehrig, G., Brooks, T., & Austin, B. (2003). *Exploring the beliefs of secondary science teachers through interview maps.* Paper presented at the meeting of the National Association of Research in Science Teaching, Philadelphia, PA.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (1998). Science teacher beliefs and intentions to implement science-technology-society (STS) in the classroom. *Journal of Science Teacher Education,* 9(1), 1–24.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching,* 37(3), 275–292.

Mamlok-Naaman, R., Hofstein, A., & Penick, J. (2007). Involving teachers in the STS curricular process: A long-term intensive support framework for science teachers. *Journal of Science Teachers Education*, 18(4), 497–524.

Mansour, N. (2009). Science teachers' beliefs and practices: Issues, implications and research agenda. *International Journal of Environmental & Science Education*, 4(1), 25–48.
Martin, A. M. & Hand, B. (2009). Factors affecting the implementation of argument in the elementary science classroom: A longitudinal case study. *Research in Science Education,* 39, 17–38.
Maxwell, J. A. (2005). *Qualitative research design: An interactive approach* (2nd ed.). Thousand Oaks: Sage.
McKernan, J. (1996). *Curriculum Action Research*. London: Kogan Publication Ltd.
McNiff, J. (1993). *Teaching as learning: An action research approach*. London: Routledge.
Mellado, V. (1998). The classroom practice of pre-service teachers and their conceptions of teaching and learning science. *Science Education,* 82(2), 197–214.
Merino, B. J. & Holmes, P. (2006). Student teacher inquiry as an "entry point" for advocacy. *Teacher Education Quarterly,* 33(3), 79–96.
Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco: John Wiley & Sons.
Miles, M. B. & Huberman, A. M. (1994). *Qualitative Data Analysis* (2nd ed.). Thousand Oaks: Sage Publishing.
Munby, H. (1982). The place of teachers' beliefs in research on teacher thinking and decision making, and an alternative methodology. *Instructional Science,* 11, 201–225.
National Research Council (NRC). (1996). *National science education standards*. Washington, DC: National Academy Press.
Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, 19(4), 317–328.
OECD (Organisation for Economic Co-operation and Development). (1999). *Measuring student knowledge and skills: A new framework for assessment.* Paris: Oe.
OECD. (2000). *Measuring Student Knowledge and Skills: The PISA 2000 Assessment of Reading, Mathematical, and Scientific Literacy*. Paris: Oe.
OECD. (2003). *The PISA 2003 Assessment Framework: Mathematics, Reading, Science and Problem Solving Knowledge and Skills*. Paris: Oe.
OECD. (2005). *Teachers matter: Attracting, developing and retaining effective teachers.* Paris: Oe.
OECD. (2006). *Assessing scientific reading and mathematical literacy: A framework for PISA 2006*. Paris: OECD.
OECD. (2009). *PISA 2009 assessment framework: Key competencies in reading, mathematics and science*. Paris: OECD Publishing.
Osborne J. & Dillon J. (2008). *Science education in Europe: Critical reflections*. *A report to the Nuffield Foundation.* London: Nuffield Foundation.
Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research,* 62(3), 307–332.
Parkinson, E. (2003). Scientific & technological literacy through TechnoScience 2000+: An approach for in-service and preservice training. *Journal of Technology Studies*, 29(1), 26–33.
Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks: Sage.

Peterman, F. P. (1991). *An experienced teacher's emerging constructivist beliefs about teaching and learning.* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL, April 3–7, 1991.

Price, J. N. (2001). Action research, pedagogy and change: The transformative potential of action research in pre-service teacher education. *Journal of Curriculum Studies,* 33(1), 43–74.

Rannikmäe, M., Laius, A., & Holbrook, J. (2010). Improving the learning environment: Students' creative thinking and reasoning skills through PARSEL teaching. In I. Eilks & B. Ralle (Eds.), *Contemporary science education – Implications from science education research about orientations, strategies and assessment* (pp. 247–252). Aachen: Shaker Verlag.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula, T. Buttery, & E. Guyton (Eds.), *Handbook of research on teacher education* (pp. 102–119). New York: Simon & Schuster Macmillan.

Robinson, J. P., Shaver, P. R., & Wrightsman, L. S. (Eds.) (1991). *Measures of personality and social psychological attitudes* (pp. 17–59). San Diego: Academic Press.

Roehrig, G. H. & Kruse, R. A. (2005). The role of teachers' beliefs and knowledge in the adoption of a reform-based curriculum. *School Science and Mathematics, 105,* 412–422.

Rokeach, M. (1968). *Beliefs, attitudes, and values: A theory of organization and change*. San-Francisco: Jossey-Bass.

Roth, W.-M. (2007). Toward a dialectical notion and praxis of scientific literacy. *Journal of Curriculum Studies*, 39(4), 377–398.

Roth, W.-M. & Barton, A. C. (2004). *Rethinking scientific literacy*. New York: Routeledge Falmer.

Sadaf, A., Newby, T. J., & Ertmer, P. A. (2012). Exploring pre-service teachers' beliefs about using Web 2.0 technologies in K-12 classroom. *Computers & Education,* 59(3), 937–945.

Savasci-Acikalin, F. (2009). Teacher beliefs and practice in science education. *Asia-Pacific Form on Science Learning and Teaching,* 10(1), 1–14.

Scott, D., & Weeks, P. (1998). Action research as reflective collaboration. In B. Atweh, S. Kemmis & P. Weeks (Eds.), *Action research in practice: Partnership for social justice in education* (pp. 239–249). New York: Routledge.

Shamos, M. H. (1995). *The myth of scientific literacy*. New Brunswick: Rutgers University Press.

Shen, B. S. P. (1975). Scientific literacy and the public understanding of science. In S. B. Day (Ed.), *Communication of scientific information* (pp. 44–52). Basel: Karger.

Shavelson, R. J. & Towne, L. (Eds.) (2002). *Scientific research in education.* Washington: National Academy Press.

Shulman, L. & Shulman, J. (2004). How and what teachers learn: a shifting perspective. Journal *of Curriculum Studies*, 36(2), 257–271.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D. et al. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching,* 36(8), 930–954.

Simon, S. & Campbell, S. (2012). Taecher learning and professional devopment in science education. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 295–306). Dortrecht: Springer.

Simpson, R. D., Koballa, T. R., Oliver, J. S., & Crawley, F. E. (1994). Research on the affective dimensions of science learning. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 211–234). New York: Macmillan.

Smith S. (2002). *The 2000 national survey of science and mathematics education: Status of high school chemistry teaching*. Retrieved March, 2012 from http://www.horizon-research.com

Smith, M. U. & Siegel, H. (2004). Knowing, believing, and understanding: What goals for science education? *Science & Education*, 13, 553–582.

Stake, R. E. (2005). Qualitative case studies. In N. K. Denzin and Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed.) pp. 433–466. Thousand Oaks: Sage Publications.

Stolk, M. J., Bulte, A. M. W., De Jong, O., & Pilot, A. (2009). Strategies for a professional development programme: Empowering teachers for contextbased chemistry education. *Chemistry Education Research and Practice*, 10, 154–163.

Strauss, A. & Corbin, J. (1998). *Basics of qualitative research: Grounded theory procedures and techniques* (2nd ed.), Thousand Oaks: Sage.

Stringer, E. (2007). *Action research*. (3rd ed.). Los Angeles: Sage Publishing.

Tabachnick, R. B. & Zeichner, K. (1998). Idea and action: Action research and the development of conceptual change teaching of science. *Science Education,* 82(3), 309–322.

Tobin, K. (2006). Qualitative research in classrooms. In K. Tobin & J. L. Kincheloe (Eds.), *Doing educational research: A handbook*. Rotterdam: Sense Publishing.

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 45–93). New York: Macmillan.

Tobin, K. & McRobbie, C. J. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education,* 80*,* 223–241.

Unal, G. & Akpinar, E. (2006). To what extent science teachers are constructivist in their classrooms? *Journal of Baltic Science Education*, 2(10), 40–50.

UNESCO. (1993). *Project 2000+: Scientific and Technological Literacy for All.* Paris: Final Report. Paris: UNESCO.

Vaino, K. & Holbrook, J. (2011). *The influence of a collaborative action research project on chemistry teacher beliefs.* In: Annual International Conference of Global Sustainability and Public Understanding of Science: The Role of Science Education Research in the International Community: NARST 2011, Orlando, FL, USA, April 3–6. Omnipress, 2011.

Vaino, K., Holbrook, J., & Rannikmäe, M. (In press). Exploring teacher change towards enhancing students' scientific literacy through classroom observations. *Journal of Baltic Science Education*.

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: the role of teachers' practical knowledge, *Journal of Research of Science Teaching*, 38, 137–158.

Van Driel J. H., Bulte A. M. W., & Verloop N. (2005). The conceptions of chemistry teachers about teaching and learning in the context of curriculum innovation. *International Journal of Science Education*, 27, 302–332.

Van Maanen, J. (1988). *Tales of the Field: On writing ethnography*. Chicago: University Press.

Vos, M. A. J. (2010). *Interaction between teachers and teaching materials: On the implementation of context-based chemistry education*. PhD Thesis, Eindhoven University of Technology.
Wallace, C. S. & Kang, N. H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing beliefs sets. *Journal of Research in Science Teaching,* 41(9), 936–960.
Wallace, J. & Loughran, J. (2012). Science teacher learning. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 295–306). Dortrecht: Springer.
Weiner, G. (2002). Professional development, teacher education, action research and social justice: A recent initiative in North Sweden. Paper presented at the Annual Conference, In-service and Professional Development Association, Birmingham, November 1–3, 2002.
Wenger, E. (1998). *Communities of Practice: Learning, meaning and identity*. Cambridge: Cambridge University Press.
Woodbury, S. & Gess-Newsome, J. (2002). Overcoming the paradox of change without difference: A model of change in the arena of fundamental school reform. *Educational Policy*, 16(5), 763–782.
Yerrick, R., Parke, H., & Nugent, J. (1997). Struggling to promote deeply rooted change: The filtering effect of teachers' beliefs on understanding transformational views of teaching science. *Science Education, 81,* 137–159.
Yezierski, E. J. & Herrington, D. G. (2011). Improving practice with target inquiry: High school chemistry teacher professional development that works. *Chemistry Education Reerach and Practice*, 12, 344–354.
Yin, R. (1994). *Case study research: Design and methods* (2nd ed.). Beverly Hills: Sage Publishing.
Yip, D. (2001). Promoting the development of a conceptual change model of science instruction in prospective secondary biology teachers. *International Journal of Science Education*, 23, 755–770.

SUMMARY IN ESTONIAN

Juhtumiuuring keemiaõpetajate tõekspidamiste muutumisest õpilaste loodusteadusliku kirjaoskuse arendamise protsessis

Rahvusvaheliselt ja ka Eestis on püstitatud eesmärk arendada õpilaste loodusteaduslikku kirjaoskust (OECD, 2009; Vabariigi Valitsus, 2011). Paraku näitavad mitmed uuringud, et õpilaste huvi loodusteaduste õppimise ja sellega seotud karjäärivalikute vastu on langenud (High Level Group on Science Education, 2007). Ühe võimaliku lahendusena probleemile nähakse sotsiaalsete ja tehnoloogiliste aspektide ning uurimusliku lähenemise sissetoomist loodusteaduste õpetamisse-õppimisse (Aikenhead, 2005). Eelpooltoodu eeldab olulisi muudatusi loodusteadushariduses ning loodusteaduste õpetajate ettevalmistuses (Osborn & Dillon, 2008). Uurimused on näidanud, et tegevõpetajate tõekspidamiste ja õpetamispraktikate muutmiseks ei piisa paaripäevastest juhuslikest koolitustest, professionaalse arengu efektiivsemaks tagamiseks on vaja õpetajate pikaajalist ning sügavutiminevat kaasamist (OECD, 2005).

Käesoleva töö põhieesmärgiks oli toetada keemiaõpetajate tõekspidamiste ja õpetamispraktikate muutumist suunas, mis aitaks efektiivsemalt arendada õpilaste loodusteaduslikku kirjaoskust. Loodusteadusliku kirjaoskuse määratlus ja vastav õpetamiskäsitlus antud töös toetub loodusteadusliku ja tehnoloogiaalase kirjaoskuse (STL) filosoofiale (Holbrook, & Rannikmäe, 2009). STL õpetamisviisi peamised komponendid on õpilaste:

a. individuaalsete oskuste arendamine;
b. sotsiaalsete oskuste arendamine;
c. uurimuslike oskuste arendamine ning ettekujutuse kujundamine loodusteaduste olemusest;
d. loodusteaduslike teadmiste omandamine (rõhuga kõrgemat järku mõtlemisoskuste kujundamisele).

Õpetajate professionaalse arengu toetamiseks STL kontseptsiooni omaksvõtmisel kasutati ühise tegevusuuringu (*collaborative action research*) formaati. Viis kogenud Eesti keemiaõpetajat koos teeside autoriga rakendasid kolmeaastase projekti jooksul (2008–2011) STL õppemooduleid keemia tundides, disainisid neli uut moodulit, evalveerisid moodulite rakendatavust praktikas ning dissemineerisid STL ideestikku ning väljatöötatud mooduleid laiemale õpetajaskonnale.

Õpetajate koostöö realiseerus peamiselt regulaarselt toimuvate kokkusaamiste kaudu, milles keskenduti: (1) kogetud STL õpetamispraktika reflekteerimisele (sh rakendumist takistavatele probleemidele ning lahenduste leidmisele); (2) tegevuste planeerimisele; (3) uute moodulite disainimisele (alates projekti teisest aastast).

Õpetajate tõekspidamiste muutumist STL õpetamisviisi suhtes uuriti kolme teguri kaudu (Ajzen, 1991): (1) õpetaja hoiak, (2) normatiivsed tõekspidamised (teiste arvamus), ja (3) õpetaja tajutud kontroll (sh eneseefektiivsus).

Metodoloogilise raamistikuna kasutati kvalitatiivset lähenemisviisi (Miles & Huberman, 1994) ning juhtumiuuringu meetodit (Yin, 1994). Andmed koguti projekti jooksul korduvalt viie erineva uurimisinstrumendiga (õpetaja intervjuu, kokkusaamiste heliülesvõtted, õpetajate mitteformaalsed kommentaarid, tunnivaatlused, õpilasküsimustik).

Uurimistulemustest selgub, et:

I. Õpetajad arendasid projekti jooksul edasi oma (positiivseid) hoiakuid STL lähenemise suhtes. Kui esimesel aastal nägid õpetajad STL õpetamisviisi peamise kasuna valdavalt õpilaste motivatsiooni kasvu keemia õppimisel, siis järgnevate aastate jooksul jõuti äratundmisele, et STL lähenemine aitab tuua vaheldust oma senisesse õpetamispraktikasse ning saavutada laiemaid õpieesmärke kui pelgalt keemiaalaste teadmiste omandamine.

   Õpetajatel tekkis esimesel aastal STL mooduleid rakendades ka rida negatiivseid tajutud kontrolliga seotud tõekspidamisi:
   a. moodulid on kompleksed ning seetõttu on neid kohati raske rakendada;
   b. STL lähenemisviisi poolt väljapakutud kujundava hindamise meetodid on liiga keerukad;
   c. ainekava läbimisel ning õpilaste eksamiteks ettevalmistamisel esinev ajapuudus.

   Projekti jooksul muutusid õpetajate negatiivsed tajutud kontrolliga seotud tõekspidamised neutraalsemaks või isegi positiivseks: kõigi õpetajate enese-efektiivsus moodulite rakendamisel ja õpilaste hindamisel kasvas. Kuigi ajapuudus, mida õpetajad tundsid moodulite rakendamisel, ei kadunud projekti lõpuks täielikult, tunnistasid õpetajad, et probleemi ühine jagamine muutis selle vähem oluliseks. Samuti hakkasid õpetajad ümber hindama oma seniseid õpetamise prioriteete (ainekava läbimiselt keskenduti laiemate õpieesmärkide saavutamisele).

   Projekti jooksul omandasid õpetajad uusi positiivseid normatiivseid tõekspidamisi: STL lähenemisviisi rakendamisel saadi tuge nii projektikaaslastelt kui ka teistelt loodusteaduste õpetajatelt, kellele STL lähenemist (nii projekti õpetajate poolt läbi viidud kahepäevase koolituse kui ka muude ühiste ülesastumiste käigus) tutvustati.

II. Ühise tegevusuuringu aspektid, mis toetasid õpetajate positiivsete tõekspidamiste kujunemist STL lähenemisviisi suhtes, võib jagada mõju iseloomu järgi kolmeks:
   a. esineb otsene seos projekti tegevuste ja tõekspidamiste muutuste vahel:

- ideede vahetamine ning STL praktika reflekteerimine projekti kokkusaamistel;
- moodulite ja hindamisjuhendite ühine disainimine;
- koolituse ühine organiseerimine ja läbiviimine;
- positiivne tagasiside projektikaaslastelt ning teistelt õpetajatelt.

b. esineb kaudne seos projekti tegevuste ja õpetaja tõekspidamiste muutuse vahel, tõekspidamised muutuvad peamiselt õpetaja individuaalsete strateegiate kasutamise tulemusena:
   - moodulite korduv rakendamine;
   - projekikaaslase tundide külastamine;
   - õpetamise efektiivsuse tõstmine jms.

c. kontekstuaalsed mõjud: õpilaste positiivne reaktsioon STL lähenemisviisi suhtes.

III. Projekti jooksul toimusid muutused õpetajate õpetamispraktikates. Võrreldes projekti algusega hakkasid õpetajad juba esimesel aastal rakendama rohkem STL lähenemisele omaseid elemente: kasutasid tundides rohkem uurimuslikke töid, tekitasid seoseid keemia, tehnoloogia ja igapäevaelu vahele, suurendasid rühmatööde osakaalu tunnis ning rakendasid kujundavat hindamist. Kuna projekti alguses olid õpetajad küllaltki erinevad oma õpetamisviisilt, siis ka STL elementide adapteerimine, nii ulatuse kui kiiruse mõttes, kulges õpetajatel erinevalt.

IV. Õpetajate õpetamispraktikate muutust tajusid ka nende õpilased. Uuringu tulemustele tuginedes võib väita, et õpilaste sisemine motivatsioon keemia õppimisel kasvas, kui õpetamisel hakati kasutama STL lähenemist.

Käesoleva töö tulemused kinnitavad ja rõhutavad, et professionaalse arengu toetamisel ning uute õpetamispraktikate rakendamisel on oluline võtta arvesse õpetajate olemasolevaid tõekspidamisi. Samuti näitab uurimus, et negatiivseid tegevuse kontrolliga seotud tõekspidamisi saab muuta õpetajate ühise tegevusuuringu kaudu, põhiliselt tänu uute praktikate tulemuslikkuse kogemisele, arvukatele vahendatud kogemustele ning koostöö käigus tekkivatele positiivsetele normatiivsetele tõekspidamistele.

ACKNOWLEDGEMENTS

I am deeply appreciative of many people for their support and inspiration throughout my graduate studies. First, I offer my sincere gratitude to my supervisors, Professor Jack Holbrook and Professor Miia Rannikmäe for their insights, guidance, support, and thoughtful advice.

I would also thank my close colleagues from the Science Education Centre: Anne, Regina, Klaara, Moonika, and Aveliis for their meaningful support and friendly atmosphere during my studies.

My deepest gratitude goes to the five chemistry teachers and their students who participated in, and contributed to, this study. Without their effort, this study would not have succeeded.

I also wish to express my gratitude to Dr. Rachel Mamlok-Naaman and Professor Avi Hofstein from the Weizmann Institute of Science, and to Professor Jari Lavonen from the University of Helsinki for their encouraging advice for improving my study.

And, finally, I would like to thank my family and friends for understanding when I had no time for them. My parents, my husband and children have been generous and encouraging throughout my studies. In addition to their moral support, they have also been interested in my study every step of the way.

PUBLICATIONS

CURRICULUM VITAE

Name: Katrin Vaino
Date of birth: 24.07.1970
Citizenship: Estonian
Work address: Science Education Centre, Faculty of Science and Technology, University of Tartu, Vanemuise 46, Tartu, 51014, Estonia
Phone: + 372 737 5083
E-mail: katrin.vaino@ut.ee

Education:

2008–...	University of Tartu, Faculty of Science and Technology, PhD studies in science education
1998–1999	Tallinn Pedagogical University, teacher qualification
1988–1992	University of Tartu, Faculty of Physics and Chemistry, diploma in chemistry

Professional employment:

2011– ...	University of Tartu, Faculty of Science and Technology, specialist
1992–2011	Kadrina Secondary School, teacher of chemistry and science

Field of research:

The design and evaluation of structures supporting change in science teachers' beliefs and practice towards enhancing students' scientific and technological literacy.

ELULOOLIRJELDUS

Nimi: Katrin Vaino
Sünniaeg: 24.07.1970
Kodakondsus: Eesti
Aadress: Tartu Ülikool, Loodus- ja tehnoloogiateaduskond, Loodusteadusliku hariduse keskus, Vanemuise 46, Tartu, 51014
Telefon: 737 5083
E-post: katrin.vaino@ut.ee

Haridustee:
2008 – ... Tartu Ülikool, loodusteadusliku hariduse doktoriõpe
1998 – 1999 Tallinna Pedagoogiline Instituut, õpetajakutse eriala
1988 – 1992 Tartu Ülikool, Füüsika-keemia teaduskond, keemia eriala

Teenistuskäik:
2011 – ... Tartu Ülikool, spetsialist
1992 – 2011 Kadrina Keskkool, keemia ja loodusõpetuse õpetaja

Teadustegevus:
Loodusteaduste õpetajate tõekspidamiste ja õpetamispraktikate muutumist toetavate struktuuride loomine ja evalveerimine eesmärgiga tõsta õpilaste loodusteaduslikku ja tehnoloogiaalast kirjaoskust.

DISSERTATIONES PEDAGOGICAE SCIENTIARUM UNIVERSITATIS TARTUENSIS

1. **Miia Rannikmäe.** Operationalisation of Scientific and Technological Literacy in the Teaching of Science. Tartu, 2001.
2. **Margus Pedaste.** Problem solving in web-based learning environment. Tartu, 2006.
3. **Klaara Kask.** A study of science teacher development towards open inquiry teaching through an intervention programme. Tartu, 2009.
4. **Anne Laius.** A longitudinal study of science teacher change and its impact on student change in scientific creativity and socio-scientific reasoning skills. Tartu, 2011.