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UNIVERSITY OF TARTU
Press

Science Education Centre, Institute of Ecology and Earth Sciences, Faculty of Science and Technology, University of Tartu, Estonia

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Supervisor: Professor Miia Rannikmäe, PhD
Professor Jack Barrie Holbrook, PhD
University of Tartu, Estonia

Opponent: Professor Cecília Galvão, PhD
Institute of Education, University of Lisabon, Portugal

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LIST OF ORIGINAL PUBLICATIONS

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

I. Valdmann, A., Holbrook, J., & Rannikmäe, M. (2012). Evaluating the Teaching Impact of a Prior, Context-Based, Professional Development Programme. *Science Education International*, *23*(2), 166–185.

II. Holbrook, J., Rannikmäe, M., & Valdmann, A. (2014). Identifying Teacher Needs for Promoting Education through Science as a Paradigm Shift in Science Education. *Science Education International*, *25*(2), 4–42.

III. Valdmann, A., Rannikmäe, M., & Holbrook, J. (2016). Determining the Effectiveness of a CPD Programme for Enhancing Science Teachers Self-Efficacy Towards Motivational Context-Based Teaching. *Journal of Baltic Science Education*, *15*(3), 284–297.

IV. Valdmann, A., Holbrook, J., Rannikmäe, M. (2017). Determining the Effectiveness of a Design-Based Continuous Professional Development Programme for Science Teachers. *Journal of Baltic Science Education, 16*(4), 576–591.

V. Valdmann, A., Rannikmäe, M., & Holbrook, J. (2018). The Meaning of Teacher Ownership and Determining Categories of Teacher Ownership. *EURASIA Journal of Mathematics, Science and Technology Education (submitted).*

The Author's contributors to the original publications are stated below:

Paper I: designing the study; formulating the research questions; undertaking data collection and analysis; writing the paper as the main author.

Paper II: participating in the creation of the study design; working out the instrument of the study; participating in the formulation of the research questions; undertaking data collection and analysis; writing the paper as the second author.

Paper III: designing the study; formulating the research questions; undertaking data collection and analysis; writing the paper as the main author.

Paper IV: designing the study; formulating the research questions; undertaking data collection and analysis; writing the paper as the main author.

Paper V: designing the study; formulating the research questions; undertaking data collection and analysis; writing the paper as the main author.

1. INTRODUCTION

A trend within education is the development of key competences (European Parliament and Council, 2006). Competences are understood as a combination of knowledge, skills, attitudes and values. From these perspectives, it is clear that the acquisition of knowledge is not enough and skills, attitudes and values are also important components to be taught. This indicates that science education is much wider than focusing on science knowledge, or even innovations in science and technology (Roberts & Bybee, 2014).

In line with this trend, Estonia has introduced a new, competence-based national curriculum (2014), which is accompanied by on-going educational reforms, intended to lead to significant changes in its school system. The aim of the science education component of the curriculum has been to bridge theoretical knowledge and the needs of the modern society, as students learn to:

> *"Develop competences seen as enhancing scientific and technological literacy. This covers the capability to undertake observations and explanations of phenomena taking place in the natural, artificial and social environment (hereinafter environment); to analyse the environment as an integrated whole, notice different problems occurring in it and make justified decisions; to utilise scientific methods and use knowledge about biological, physio-chemical and technological systems to solve problems; to value science as a part of culture and to follow a sustainable lifestyle."(Estonian National Curriculum for Upper Secondary Schools, appendix 4, 2014).*

Other studies have widened the scope of science education, emphasising:
(a) The nature of science (DeBoer, 2000; Karisan & Zeidler, 2017).
(b) The development of the student, both in terms of intellectual development and in terms of attitudes and aptitudes (Bybee, 1997; Roberts, 2011).
(c) Society endeavours linked to interpersonal relationships and making informed socio-scientific reasoning and decisions within society (Romine, Sadler, & Kinslow, 2016; Sadler & Zeidler, 2009).

In promoting the wider scope for science education, 'education through science' is proposed as a paradigm shift in education philosophy (Holbrook & Rannikmäe, 2007). With such a paradigm shift leading curriculum reforms in science education, this requires changes in teaching strategies. Internationally, an important focus is suggested as context-based teaching (Gilbert, 2006; King, 2012; Walan & Mc Ewen, 2017). Other key foci are indicated as:
(a) Students' motivation (Bybee & McCrae, 2011; Osborne, Simon, & Collins, 2003; Wang & Liou, 2017).
(b) Inquiry based learning (IBL) (Capps & Crawford, 2013; Crawford, 2000; Özdem Yilmaz & Cavas, 2016).

(c) Argumentation and decision-making (Osborne, Erduran, & Simon, 2004; Özdem Yilmaz, Cakiroglu, Ertepinar, & Erduran, 2017; Sadler & Zeidler 2005).

However, few teaching/learning materials seek to encompass all these important aspects at once. Useful attempts can be found in EU projects, such as PARSEL (Holbrook, 2008a) and PROFILES (Bolte et al., 2012), PATHWAY (Bogner, 2014), and Ark of Inquiry (Pedaste et al., 2014), which focus on developing motivational, inquiry-based and/or decision making teaching/learning materials. The current study pays attention to all four aspects (context, motivation, inquiry-based learning and socio-scientific decision-making) and promotes teaching/learning materials seen as being motivational, context-based science teaching (MCST).

A Tartu declaration (2010), stemming from participants' views in an international conference, recognises that another key factor for promoting meaningful science education is the support for the teacher. The declaration stresses the need to focus on developing high-quality teachers, through well-developed pre-service provisions and also proposes giving attention to in-service education in the form of continuous professional support. This is indicated as essential in order for teachers to create sustainable rich, relevant, interesting, current and timely science and technology lessons. The declaration suggests that an important approach to promoting teacher professionalism is through the development and enactment of carefully devised, professional development programmes (Darling-Hammond, Hyler, & Garder, 2017; Kennedy, 2005; Wallace & Loughran, 2012). Teacher professional programmes pay attention to a number of factors, such as determining the needs of teachers with respect to promoting student learning within the science classroom and the importance of reflecting on the format of continuous professional development (CPD) programmes appropriate for teachers. In fact, numerous CPD programmes have been developed, which focus on introducing a philosophy-based, in-service training model, or approach (Brand & Moore, 2011; Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Saunders & Rennie, 2013; Van Dijk & Kattmann, 2007; Witterholt, Goedhart, Suhre, & van Streun, 2012) and measuring the effectiveness of in-service courses (Desimone, 2009; Harland & Kinder, 2014; Whitworth & Chiu, 2015). However, although many studies have provided detailed accounts of the effects of their programmes, the manner in which these strategies for professional development have been transformed into specific activities within a professional development programme remains unclear.

To overcome the gap between reform expectations and the actual, existing teaching in the classroom, research over the last two decades has focused on examining an understanding of teacher needs. A wealth of research evidence has shown that teacher needs are related to teacher self-efficacy, this being a significant indicator of teacher behaviour in the classroom (Bandura & Cervone, 1983; Bandura, 1997; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Tschannen-Moran, 1998; Woolfolk Hoy & Davis, 2006). Research has also emphasised that a change in teacher self-efficacy has been seen as a precursor to classroom change, playing a critical role in promoting education.

Nevertheless, there have been concerns that an innovation, to be successful, requires teachers to go beyond self-efficacy and gain ownership of the innovation (Simon, Campbell, Johnson, & Stylianidou, 2011). Teacher ownership of an innovation can be expressed by a philosophical identification with it, putting the innovation into operation as intended and by communicating successes deriving from the innovation and the accompanying personal experiences (Pierce, Kostova, & Dirks, 2003). There is a danger that without striving for ownership, teachers are likely to be insufficiently prepared for implementation of a new development, such as promoting a competence-based curriculum.

Focus of the research

This study sets out to determine:

(a) Science teacher professional needs, to be met through the design and implementation of a CPD programme intended to raise teaching skills and perceptions to promote scientific and technological literacy among students.
(b) The increase in science teacher's self-efficacy, based on outcomes from a continuous professional development (CPD) programme, designed to meet science teacher professional needs from educational, philosophical and classroom operation perspectives.
(c) The effectiveness of the design and operation of the CPD programme in changing the science teaching approach, enabling a teaching focus on student motivation, inquiry-based learning and promoting students' ability to undertake socio-scientific decision-making, befitting a competence-based curriculum.
(d) Levels of science teacher ownership, post-CPD programme and follow-up intervention, to determine the conceptualisation of the proposed philosophy, operationalisation of the intended teaching approach and the manner in which this is perceived for conveyance to others.

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

(a) To create and undertake an effective, continuous professional development programme (CPD) for science teachers, modelled on identified teacher needs, to promote their self-efficacy with particular reference to self-confidence and self-competence, based on an 'education through science' philosophy.
(b) To determine the effectiveness of a CPD programme, based on science teacher feedback and self-efficacy in operationalising a teaching approach, highlighting student motivation, scientific problem solving and socio-scientific decision-making, based on an 'education through science' philosophy.
(c) To define and identify teacher ownership levels, based on characteristics of conceptualising and operationalisation of post CPD follow up by science

teachers, based on indicators related to the internalisation of the philosophy and teaching approach, as advocated through the CPD programme and their preparedness to convey the philosophy and approach to other teachers.

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

1. What do teachers, who had previously been introduced to 'education through science' philosophy-based teaching modules, recommend for inclusion and delivery within a planned, continuous professional development (CPD) programme to raise its effectiveness for other science teachers? (Paper I).
2. What are science teachers' professional needs to raise their self-efficacy to promote motivational, context-based student science learning associated with a competence-based curriculum? (Paper II).
3. What components of a CPD programme are deemed effective in raising science teacher's self-efficacy, identified by teacher reflections on trying out the proposed teaching approach? (Paper III, IV).
4. What are the main characteristics of teacher ownership, which enables the determination of levels of teacher ownership in conceptualizing and operationalising a motivational, context-based teaching approach? (Paper V).

The research questions are addressed in the following original publications**:**

Paper I addresses research question 1. Teachers' opinions and suggestions, taken into account in planning a CPD programme, are strongly interconnected with the stages promoted in teaching-learning modules. Their opinions are seen as important in determining ways to give additional guidance, support and encouragement in enacting context-based, inquiry-based student learning, as well as promoting the teaching of argumentation and reasoning skills. This is expected to be by enabling participants in the devised and undertaken CPD programme to gain pedagogical content knowledge (PCK) with a philosophical underpinning to work through teaching-learning modules collectively and for the teacher to appreciate and enact the approach.

Paper II explores research question 2 and addresses teacher identified, science teaching professional needs, based on responses to a devised and validated instrument

Paper III and IV explore research question 3 and evaluate the immediate effectiveness of a continuous professional development (CPD) programme against associated teacher profiles. Teachers evaluate the CPD programme in terms of gains in teacher self-efficacy to undertake motivational, context-based science teaching (MCST), through the effective use of purposely design teaching-learning modules. Through interviews, teachers highlight components of the CPD programme, which raise their self-confidence in implementing MCST, and these components, are shown to be consistent with Bandura's self-efficacy determinants (mastery experience, vicarious experience and verbal persuasion) as well as socio-cultural constructivism attributes.

Paper V addresses research question 4. The professional development programme positively impacts on teachers' ability to handle 3-stage 'education through science' teaching-learning materials in the classroom. Teacher permanent change towards internalising the philosophy was seen as: (1) paradigmatic, (2) experiential or (3) emotional ownership, reflecting on the degree to which teachers conceptualised the motivational context-based, science teaching philosophy and the operationalization of the 3-stages of the 'education through science' philosophy in developing teaching/learning modules. Only teachers indicating paradigmatic ownership are shown to be at the highest professional level and capable of acting as in-service providers for future teachers.

2. REVIEW OF THE LITERATURE

2.1. Goals, Philosophy and Approach for Science Teaching

2.1.1. Goals of Science Teaching

Papers II and I indicate that over many decades, authors have continued to question the goals of science education and how best to achieve those goals (Hurd, 1958; Miller, 1997; Norris & Philips, 2003; Roberts & Bybee, 2014). Although it has been generally agreed that the goals of science education can be expressed as the enhancement of scientific literacy (Estonian National Curriculum, 2014), Roberts and Bybee (2014) indicate that scientific literacy can perhaps be conceptualised in two major camps, or points of view:

(a) Those who advocate a central role for the knowledge of science (Vision I).
(b) Those who see scientific literacy referring to usefulness in society, involving personal decision making about contextually embedded science within social issues (Vision II).

However, there seems to be confusion as to the emphasis to place on the two visions. Science education reforms (Eurydice, 2011; NRC, 2012; EC, 2015) emphasise that students should have a scientific and practical understanding of the need for science in society. Understanding the consequences of the scientific development in society is a prerequisite for socially responsible persons to make good decisions and enrich their lives (Sadler & Zeidler, 2009). In fact, the interdependence of science and society is at the heart of scientific literacy, noting that in a knowledge society, there is a need to shift from the scientific literacy of Vision I towards Vision II, perhaps resulting in an intermediary position in which both Vision I and Vision II are present (Aikenhead, Orpwood, & Fensham, 2011). Whichever view of scientific literacy is taken, it is a complex, multidimensional construct (Bybee, 1997) and consists of multiple components (subject, personal and societal issues relating to science knowledge, understanding the nature of science, awareness of the impact of science and technology on society, etc.) (Holbrook & Rannikmäe, 2007). It is thus not surprising that there is no single accepted definition of scientific literacy.

Noting the strong interrelationship between science and technology within society, where technological processes tend to be dependent on scientific developments, Holbrook and Rannikmäe (2009, p. 286) put forward a definition of scientific and technological literacy (STL) as:

> "*Developing an ability, to creatively utilise appropriate evidence-based scientific knowledge and skills, particularly with relevance for everyday life and a career, in solving personally challenging yet meaningful scientific problems as well as making, responsible socio-scientific decisions*".

This definition not only recognises the importance of technology interrelating with science, but that science education needs to enable students to acquire educational attributes at the subject (the nature of the subject), personal (skills and attitudes) and social (interacting skills and values) levels. Similar features are highlighted within recent PISA reports (OECD, 2016), where it is indicated that a scientifically literate person is expected to be able to appreciate and understand the impact of science and technology on everyday life, make informed personal decisions about issues and topics that involve science, read and understand the essential points of media reports about matters that draw on science, and reflect critically on the information. This can be seen as a good example of how to interconnect (link) the vision I and vision II associated with scientific literacy, or scientific and technological literacy, such that both Vision I and Vision II are present.

2.1.2. An 'Education through Science' Philosophy

The term 'education through science' (EtS) (Holbrook & Rannikmäe, 2007; Holbrook, 2010) is proposed as a philosophy (Paper II), with the intention to develop a revised teaching-learning approach, geared to international trends in science education and the development of key competences in students (NRC, 2010; 2012). To highlight the philosophical change, Paper II points out a comparison of 'education through science' with the more standard expression 'science through education'.

'Education through science' focuses on students' educational gains and stresses the learning to be acquired through science lessons. It sees education as the focus and science as the vehicle (that which is providing the content). Both cognitive knowledge and process skill goals, intended as part of the intellectual development of students, are important, as well as skills associated with the development of the person and those related to the social situation, social values and interpersonal relations. Science education is thus far more than an understanding of science conceptual ideas.

'Science through education' sees the work of scientists as a focus and education as the learning emanating from this. The education offered is through the science and is limited by the perception of the scientific enterprise. In this approach, school science is educational, of course, because it is learning science knowledge, science processes and the ways of working of scientists. While it does not necessarily ignore the society, the learning is related mainly to uses, or applications of science within the society. It glorifies in the technological applications of scientific ideas whether these are related, for example, to medicine, the environment, engineering, or information technology. Where these applications engage ethical issues, the educational learning follows a scientists' path and relates to such issues from a scientist's perspective.

Table 1 draws together ideas on such a paradigm shift from five perspectives – purpose, vision, curricula, teaching and assessment. This is a modification of the table in Paper II and adds a further column labelled 'target aspect' so as to give further clarification.

Table 1. Paradigm Shift from a 'Science through Education' to an 'Education through Science' Philosophy (modified from Paper II)

Paradigm Shift	Target Aspect	Shift FROM	Shift TO
1	The Purpose of School Science	Being academic, science subject-based knowledge (through isolated sub-disciplines).	Meeting the full range of educational goals through promoting student abilities for self-actualisation within a future society.
2	The Vision of Science	Science seen 'as a body of knowledge' and presented as academic content.	Science as 'a way of thinking', places emphasis on understanding the Nature of Science (NOS) (based on rigor of evidence, reproducibility, society-influenced, culturally embedded, and recognising science is not the truth, there are differences between theories and laws and acceptability based on lack of falsified rather than verification).
3	School Science Curricula	A dominance of a theoretical, conceptual view of science as fundamental for the gaining of life skills.	A competency-based approach to the gaining of abilities to utilise knowledge, skills and inculcate values and positive attitudes in line with a view of the need for scientific literacy.
4	Science Teaching Approach	A teacher centred delivery of subject matter.	A student-centred approach, spearheaded by inquiry learning in which students are guided to ask the scientific questions and then participate in answering through problem solving activities.
5	Science Assessment Approach	A predominance of assessment of content acquisition, largely undertaken by assessment of learning after teaching has been completed.	Assessment of abilities gained by placing emphasis on assessment for learning during the teaching - learning process using a variety of assessment techniques, supported by subsequent criteria-based attainment measures.

Within education through science, a proposed paradigm shift in science education (Holbrook, 2008b) suggests that more attention needs to be paid to the nature of science (NOS), students' personal and social development, recognising the goals of science education as focusing on science and technological literacy (STL) for all. This inevitably requires attention to how teachers perceives their task in the classroom and how far teachers see the importance of student motivation, interdisciplinary knowledge and classroom atmosphere as key aspects of pedagogical content knowledge (PCK). And if the paradigm shift is to be meaningful, then student gains are important and indicators of these are also of major importance.

2.1.3. 3-Stage Teaching Approach

Paper II points out that a major concern in science teaching, at least in developed countries, is the lack of students' positive attitudes towards school science (EC, 2007; Osborne, Simon, & Collins, 2003). For this, Deci and Ryan (2000) suggested the need to stimulate intrinsic motivation in students.

Paper II points out that emphasis needs to be placed on the development of context-based teaching (Gilbert, 2006) in line with the suggestion that classroom instruction in science needs to move away from strictly content-based and value-free instruction and toward a socio-cultural approach, in which students are active participants in a decision-making process (Aikenhead, 2006).

Paper II introduces a 3-stage model, which is distinguished from other approaches in that it emphasises intrinsic motivation through a socio-scientific context, prior to embarking on inquiry-based science learning and then following this up by socio-scientific decision-making. The 3-stage model (Holbrook & Rannikmäe, 2010), is grounded on the 'education through science' (EtS) philosophy (Holbrook & Rannikmäe, 2007) and Activity Theory (van Aalsvoort, 2004a, b), with the model emphasising student active learning.

Paper I describes the three stages as:

Stage 1 the stimulating students' through intrinsic motivational stage, initiated by a carefully chosen title perceived to be relevance for students. The goal of stage 1, however, goes beyond students' desire to be involved and, by means of a scenario, seeks to motivate students to recognize the importance of attaining the science underlying the socio-scientific scenario.

Stage 2 picks up on the students need to acquire conceptual science learning and through an inquiry-based science education approach, students are guided to obtain evidence associated with gaining the science and scientific skills, identified as important by students. It includes also, as appropriate, the promoting of students' creative or ingenious thinking, as well as encouraging student-student collaboration and an awareness of safe working, self-responsibility and self-determination.

Stage 3 is the consolidation phase for the science learning, in which the acquired science is transferred into a socio-scientific decision making situation, thus promoting argumentation/reasoning skills to reach a consensus, first within a small group and then for the class as a whole. The socio-scientific component enables the inter-relating of science conceptual development with social impacts such as ethical dimensions (Saunders & Rennie, 2013).

2.2. Teacher Professional Development

Paper II points out that the development of teacher professionalism is a crucial element in seeing the 'education through science' philosophy being meaningfully implemented. It stress that an important approach to promote teacher professionalism is through the development and enactment of professional development programmes related to the needs of the teacher.

2.2.1. Continuous Professional Development

The concept of CPD for teachers is often ill defined, with the separate notion of formal training and on-job learning serving to confuse the issue further. Day's (1999) definition of CPD encompasses all behaviours, which are intended to effect change in the classroom and is stated as:

> *"Professional development consists of 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, which contribute, through these, to the quality of education in the classroom. It is the process by which, alone and with others, teachers review, renew and extend their commitment as change agents to the moral purpose of teaching; and by which they acquire and develop critically the knowledge, skills and emotional intelligence essential to good professional thinking, planning and practice with children, young people and colleagues throughout each phase of their teaching lives" (Day, 1999, p.4).*

In order to be effective, research indicates CPD programmes need to:

(a) Take account teachers self-efficacy beliefs and prior knowledge (Brand & Moore, 2011; Desimone, 2009; Howe & Stubbs, 1997; Posnanski, 2002).

(b) Teachers are involved in planning and decision making from the onset (Blonder, Kipnis, Mamlok-Naaman, & Hofstein, 2008; Brand & Moore, 2011; van Driel, 2005).

(c) Active and practice-oriented (Clarke & Hollingsworth, 2002; Day, 1999; Desimone, 2009; Lee, 2000) and meaningfully located in teachers' classrooms (Darling-Hammond et al., 2017; Putnam & Borko, 2000; Vaino, Holbrook, & Rannikmäe, 2013), sharing the best practice (McLaughlin & Talbert, 2001).

(d) Supportive social context with enough time for reflection and revision (Howe & Stubbs, 1997).
(e) Presentations and workshops have been arranged in which the new skills have been described and demonstrated, and teachers have opportunities to reflect on their own performance (Joyce & Showers, 1995).
(f) Content focused CPD that focuses on teaching strategies associated with specific curriculum content supports teacher learning within teachers' classroom context (Darling-Hammond et al., 2017; Desimone, 2009).
(g) Coaching and expert support involve the sharing of expertise about content and evidence-based practices, focused directly on teachers' individual needs (Darling-Hammond et al., 2017).
(h) Take account Bandura's proposed four methods of assimilating new sources of information (mastery experiences, vicarious experiences, verbal persuasion, and positive emotional tone) that changes both self-efficacy beliefs and behaviour (Posnanski, 2002; Ross & Bruce, 2007).

It is noteworthy that a number of researchers have indicated effective educational reform only occurs when teachers' prior knowledge, attitudes, and beliefs are seriously taken into account (Haney, Czerniak, & Lumpe, 1996; Trigwell, Prosser, & Taylor, 1994).

2.2.2. Teacher Needs to Promote 'Education through Science' Teaching Approach

Paper II provides a comprehensive overview of the theoretical concept of Teacher's Needs to promote the 'education through science' philosophy and teaching approach. Holbrook and Rannikmäe (2007) point out that science teacher needs guidance from three perspectives:
(a) A vision for science education for promoting 'education through science'.
(b) Operational skills for science teachers in promoting key competences.
(c) The background required by science teachers for teaching.

Figure 1 summarises the teacher professional needs component as described in Paper II. While the vision relates to the goals of science education as associated with STL and amplified in 2.1.1, other key aspects are associated with the nature of science and student motivation.

The nature of science eludes many teachers but is suggested that (AAAS, 1993) learning about science – its history and methodology – will have a positive impact on the thinking of individuals and will consequently enrich society and culture. That is, NOS learning will have a flow on effect outside the science classroom. Although no absolute consensus exists, Schwartz, Lederman and Crawford (2004) suggested consensus does exist with respect to seven elements:
(a) The empirical nature of science, where students should be able to distinguish between observation and inference.

(b) Scientific laws are descriptive statements of relationships among observable phenomena and thus differ from theories as inferred explanations for observed phenomena or regularities in those phenomena.
(c) The creative and imaginative nature of scientific knowledge, where ‘science’ is empirical.
(d) The theory-laden nature of scientific knowledge, where it is held that ‘scientists’ hold theoretical and disciplinary commitments, beliefs, prior knowledge, training.
(e) The social and cultural embeddedness of scientific knowledge.
(f) There is no single scientific method that would guarantee the development of infallible knowledge.
(g) The tentative nature of scientific knowledge, where it is maintained that scientific knowledge, although reliable and durable, is never absolute or certain.

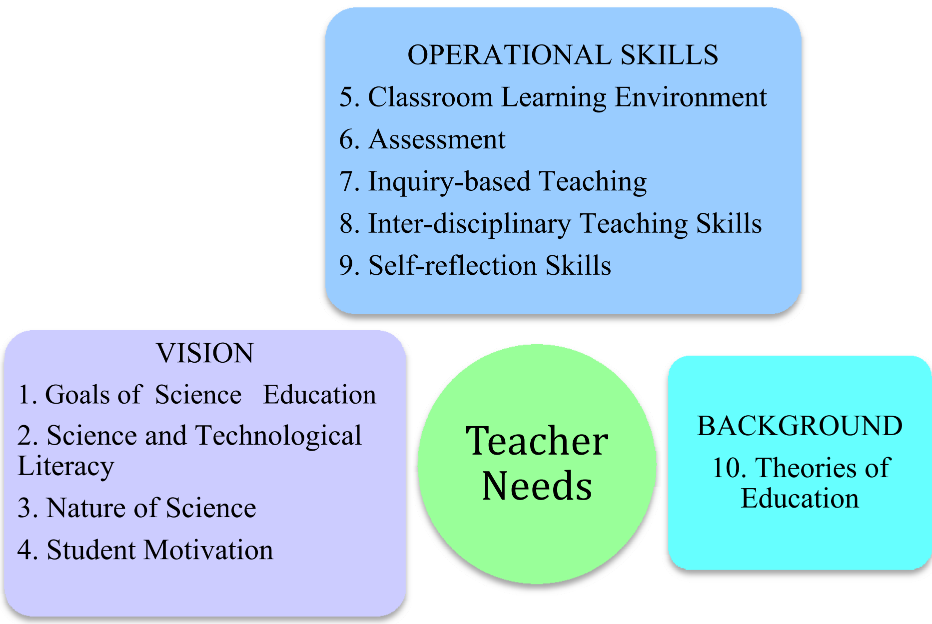

Figure 1. Teacher Professional Needs to Operationalise EtS Teaching Approach (based on Paper II)

Paper II suggests that while it is uncertain, in specific situations, whether motivation drives interest, or interest and relevance instigate motivation, student motivation is a powerful component in school education. Student motivation is strongly related to interest and enjoyment and these are very much associated with interest, and interest in turn is often associated with relevance. Cavas (2011), quoting Tuan, Chin, and Sheh (2005), suggests five important factors for motivation in science learning: student self-efficacy, perceived value (relevance/ usefulness) of science learning, learning strategies employed by the teacher, student's individual learning goals, and inevitably, the learning environment. In addition, a suitable challenge within the zone of proximal development (Vygotsky, 1978) is added.

In promoting science teaching to engage students in a motivational manner and undertake inquiry-based learning and make socio-scientific discussions, paper II recognises the importance of a number of key teacher skills as: organizing classroom-learning environment (Cavas, 2011; Rannikmäe, Teppo & Holbrook, 2010), interdisciplinary teaching skills (Dillon, 2008; Mikser, Reiska, Rohtla & Dahncke, 2008; Strathern, 2007), inquiry-based teaching skills (EC, 2007; Dudu & Vhurumuku, 2012; Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013; Spronken-Smith et al., 2011), assessment skills (Holbrook, 2008b; Romine, Sadler, & Kinslow, 2017) and reflection skills (Bolte et al., 2012; Kaune, 2006).

Paper II indicates that teachers need to be conversant with a variety of theories of education so as to successfully utilise teaching strategies conversant with an 'education through science' philosophy.

2.2.3. CPD Models

As amplified in Paper IV, professional development models for teachers have been extensively based on Shulman's (1986) concept of professional content knowledge (PCK) (Kind, 2009). Nevertheless, it is important to recognise that new developments, such as shifts towards interdisciplinary, need to recognise also teacher requirements for gains also in content knowledge (CK).

Several models exist in the literature for devising continuous professional development (CPD) programmes, for example:

(a) ERTE – reconstruction for teacher education (Van Dijk & Kattmann 2007).
(b) IMTPG – Interconnected Model of Teachers` Professional Growth (Clarke & Hollingsworth, 2002; Witterholt et al., 2012).
(c) Science Teaching Professional Development Models (Posnanski, 2002).
(d) Professional Learning Communities (Lakshmanan et al., 2011).
(e) Concern model (Hall & Hord, 2011; Sormunen, Keinonen, & Holbrook, 2014).
(f) Participatory Design Model (Kyza & Georgiou, 2014).

All of these models are more or less connected with either constructivism, or socio-cultural theory.

According to Howe and Stubbs (1997), a constructivist plus socio-cultural model can be used as an approach within a teacher PCK programme to emphasise teachers' understanding of the world, building on their prior knowledge of themselves and their experiences. They found that teacher changes in instructional practices resulted from constructing their knowledge in a supportive social context with time included for reflection and revision. Their model recognized the gaining of knowledge as a social practice and teachers were provided with opportunities to construct new knowledge in an environment that supported creativity and the free exchange of ideas.

The opportunities for processing, implementing and reflecting, provided by this socio-cultural approach, afforded teachers opportunities to deconstruct and rationalise their initial conceptions while adapting alternative approaches. Also using a constructivist, socio-cultural professional development model, Brand and Moore (2011) showed the benefits of teachers being involved in planning and decision-making from the onset; teachers learned through their investigation and meaningful engagement; teachers were active participants in both goal-setting and the on-going work of the professional development process.

Also using a constructivist, socio-cultural professional development model, Brand and Moore (2011) have shown benefits when teachers are involved in planning and decision-making from the onset; teachers learn through their investigation and meaningful engagement.

Paper III explains the choice selected as the Constructivist Socio-Cultural Professional Model (CSPM) recognising that both constructivism and socio-cultural ideas are important. In both, constructivism and sociocultural theory, four principles are regarded as important as defined by Fosnot (1989) and Rogroff & Lave (1984). Fosnot (1989) has defined constructivism with respect to the following principles:

(a) New knowledge is built on past constructions.
(b) Constructions come about through assimilation and accommodation.
(c) Learning is a process of invention rather than accumulation.
(d) Meaningful learning occurs through reflection and resolution of cognitive conflict.

These suggest teachers can construct new knowledge through social interactions in a context that encourages creativity and the free exchange of ideas. Teachers can adapt their experiences and knowledge of science education and teaching in the process of developing activities to use in their classroom.

2.2.4. Teacher as Teacher, Teacher as Learner, Teacher as Reflective Practitioner

Shulman (1987) indicated that pedagogical content knowledge (PCK) could be viewed as a combination of subject content knowledge (CK) and teaching skills, based on professional endeavours.

> *"PCK represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction"* (Shulman, 1987, p. 8).

For teachers to undertake a paradigm shift or reflect on new ideas, teacher guidance is needed. The literature recognises that teacher needs can be met in 3 important ways (Bolte et al., 2012):

(a) Learning from others when the teacher can be said to be functioning as – 'teacher as learner'.

(b) Acquiring teaching skills when the CPD focus is on developing the 'teacher as teacher'.

(c) To promote-skills for the 'teacher as a reflective practitioner'.

The teacher as a learner component supports teachers, when appropriate, with additional subject content knowledge (CK) in order to enable teachers to be more conversant with the interdisciplinary nature of the science content and pedagogical knowledge (PK).

The teacher as an effective teacher includes equipping teachers with pedagogical content knowledge (PCK), where identified as a need, such as in contemporary student-centred, constructivist teaching methods, using an IBSE approach and a relativist, classroom environment for stronger motivation and to ensure science is taught in a relevant manner for both boys and girls.

Reflection is seen as an important component of professional learning and hence teacher development. Dewey (1933) defined reflection as:

> *"Active, persistent, and careful consideration of any belief, or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends"* (p. 9).

The teacher as a reflective practitioner involves developing teachers, individually and collectively, to evaluate their teaching by analysing the teaching of modules from the perspective of their impact on students' intrinsic motivation, inquiry learning, and cooperative/collaborative learning and assessment/ feedback strategies. Based on the classroom experiences in operationalising 3-stage teaching approach in the classroom, a reflective teacher is expected to facilitate meaningful experiences for themselves.

Reflection has an important place in many in-service programmes (Brand & Moore, 2011; Clark & Hollingsworth, 2002; García et al., 2007; Kerstin, Givvin, Sotelo, & Stigler, 2010; Moore-Russo & Viglietti, 2011; Moore-Russo & Wilsey, 2014; Sherin & Han, 2004; Shulman & Shulman, 2004; van Es & Sherin, 2010), thus helping to increase teachers' self-efficacy or change their beliefs and practice (Brand & Moore, 2011; Clark & Hollingsworth, 2002).

Schön (1983) introduced the terms 'reflection-in-action', referring to the ability to reflect, or think about what was occurring while it occurred and 'reflection-on-action', to refer to reflecting, or thinking about what had already occurred. This was seen as purposeful revisiting of the past, often to consider critical events. Later, Killion and Todnem (1991) added 'reflection-for-action' as the process of reflecting on past actions and decisions seen as a means to guide future practices.

Reflection could be seen as productive, when it was comparative (i.e. views a crucial incident from a variety of perspectives), or critical (i.e. involved questioning perspectives that led to new ideas) (Hayden, Moore-Russo, & Marino, 2013). Fund (2010) depicted productive reflection as reflections that were at a “higher level extending beyond the immediate situation.” Reflection might also be deemed productive, because it considered what had been noticed in light of other perspectives (Jay & Johnson, 2002), including personal experiences, practical knowledge, educational theory and professional development (Fund, 2010). With this emphasis, Davis (2006) asserted productive reflection involved integrating the idea that four aspects of teaching (learners and learning, teaching and instruction, assessment, and subject matter knowledge) were noticed, emphasized and linked together. Smyth (1989) and likewise Larrivee (2008) suggested that reflection, as a critical component in its various forms, could actually be expressed at four levels: describing, informing, confronting and reconstructing (Paper IV).

2.3. Teacher Gains

Research has shown that continuous professional development (CPD) programmes can change teacher’s beliefs and teaching styles (Hofstein, Carmi, & Ben-Zvi, 2003; Bryan, 2012) and the training programmes that last throughout the school year are more efficient than isolated, one or two-day programmes (Brand & Moore, 2011; Lumpe, Haney & Czerniak, 2000; NRC, 1996; Posnanski, 2002). A major component for successful CPD programme are that they enhance teacher’s self-efficacy and pave the way for teachers to acquire ownership of the intended philosophy and teaching approach and are also able to guide other teachers in appreciating these.

2.3.1. Self-Efficacy

Paper III emphases the need to promote teacher self-efficacy. Bandura (1977) introduced the concept of self-efficacy beliefs and proposed that belief (confidence) in one’s abilities (competence) was a powerful driving force that influenced ‘motivation to act action’. Teachers need to build up their competence to appreciate new teaching directions. But this is not enough. Teachers also need the confidence to use the ideas in their teaching. This competence and confidence can be described as self-efficacy.

Bandura (1977) also indicates that self-efficacy is malleable, can be changed given the appropriate environment and that self-efficacy beliefs are developed from four main sources:

(a) Enactive mastery experience.
(b) Vicarious experience.
(c) Social and verbal persuasion.
(d) Physiological and affective states.

Mastery experiences refer to efficacy information gained from an individual´s performance on a particular task and is seen as the most direct and most powerful sources of information in the development of self-efficacy. An increase in self-efficacy occurs when individuals master or achieve success at a certain task and self-efficacy is lowered, when there is a failure (Bandura, 1997). Teacher efficacy is enhanced in enacting mastery when some form of self-reflection is included (Henson, 2001; Ross, 1994). Henson (2001) shows that engaging teachers in participatory research, by involving teachers in collaborative development with each other, as well as constructive interventions, improves teacher efficacy.

Most authors, when referring to research involving teachers, tend to use the term action research. This uses a minimum of four stages: (1) planning, (2) acting, (3) observing, and (4) reflecting (e.g. Lewin, 1946, in McKernan, 1996). According to Eilks and Ralle (2002), the above-described approach can be called participatory action research, if seen as operating through the slightly rephrased four stages as:

(a) Development of teaching strategies and materials.
(b) Testing in practice.
(c) Evaluation.
(d) Reflection and revision.

Vicarious experience, however, is more indirect and occurs when an individual observes someone else modelling a certain skill, or behaviour (Bandura, 1977). It is most successful when somebody carries it out with similar ability and similar attributes, such as age and gender. An effective CPD can be expected to pay attention to promoting teacher's vicarious experiences.

Social and verbal persuasion occurs when the individual is given social encouragement and verbal praise. The most beneficial use of verbal persuasion is when it is associated with the analyses of enactive mastery experiences, positively framed feedback in relation to goals has also been found to enhance efficacy (Bandura & Cervone, 1983). Ross and Bruce (2007) finding show that a professional development programme, taking into account Bandura`s four determinants of self-efficacy, has a positive impact on a teacher's ability to handle student management issues in the classroom.

Swars and Dooley (2010) have also suggested that inadequate science content knowledge may lead to lowered personal self-efficacy, thus underlining the importance of both content and pedagogical components in CPD programmes. Ross and Bruce (2007) found that a professional development program that took into account Bandura's four determinants of self-efficacy had a positive impact on teachers' ability to handle student management issues in the classroom (interaction increase the prospects of vicarious experience).

2.3.2. Teacher Ownership

Pierce, Kostova, and Dirks (2003, p.86) define psychological ownership, as

> *"The state in which individuals feel as though the target of ownership, or a piece of that target, is theirs."*

Applying this definition to teachers as individuals, with innovative science teaching as the target, can be called 'teacher ownership'. Teacher ownership of an innovation such as implementing a new philosophy using a suitable teaching/ learning model is thus more than a belief (confidence) in one's abilities (competence) influencing 'motivation to act action' i.e. it can be seen as a stage beyond self-efficacy as put forward by Bandura (1977). It is an internalisation of the conceptualisations involved to such a degree that this recognition can be expressed to others. This suggests that teacher ownership is associated with 'innovation to act' (Pierce, Kostova, & Dirks, 2001). Teacher ownership of an innovation is seen as self-led and involves exhibiting, from a personal viewpoint, that the attributes have been accepted, internalized, and possible adapted and then evidence of such ownership is given e.g. creating appropriate teaching materials, using appropriate teaching materials in teaching, running CPD for others.

In the literature, teacher ownership seems to be seen from three perspectives:

(a) A sense of ownership (Saunders et al., 2017).
(b) Towards teacher ownership (Hofstein, Katchevich, & Mamlok-Naaman, 2012).
(c) Appropriate, permanently attained attributes (Rannikmäe, 2001).

If the innovation and approach are deemed to be acceptable to teachers, it can be seen as a sense of ownership and thus a first step in the change process for the future, which can be continued even when the extrinsic motivator (e.g. the CPD) is no longer needed. Rannikmäe (2001) called this implementation of the change over time beyond the instructional exposure, a permanent change, which describes continuous, purposeful teaching, explicitly along the lines of a philosophy and approach provided in a CPD course, plus a willingness to share best practices with others. Teacher ownership is thus beyond simply doing as guided and encompasses the need to share and provide guidelines to others. The degree to which a teacher is able to do this can relate to the degree of acceptance of the philosophy associated with ownership, the degree to which innovation takes place in taking steps to adapt to the teaching environment and the degree to which the philosophy is ultimately portrayed to others.

Between the sense of ownership and the full teacher ownership can be consider the towards ownership concept. Here, there is recognition that further steps beyond self-efficacy are needed and that the final ownership level has yet to be reached. The full teacher ownership is being able to internalise the ideas as intended, put them into operation as expected and also to be able to teach others as per the intended philosophy and approach. It is thus an additional dimension beyond a self-vision of one's capability. This indicates that just because a teacher has high levels of self-efficacy, it does not mean the teacher goes beyond this self-perception to reach the ownership stage i.e. the stage where others can compare the intention and actual vision and where the teacher makes the ideas the teacher's own and, if appropriate, even develops them further based on the intended philosophy. The final ownership stage of the innovation is the real target of any CPD programme, when the philosophy being promoted by a provider or the system and the philosophy, the teacher is conceptually able to absorb and also promote to others, becomes one and the same. This suggests that undertaking a CPD programme by itself is not enough; a further post CPD stage is needed.

Hofstein et al. (2012) suggested that in order to develop a sense of ownership among teachers, it is vital to develop the teachers as learners and as practitioners in their classroom. In other words, the goal should be to equip the teachers with the relevant content knowledge and the aligned PCK (pedagogical content knowledge). These two developments, namely the teacher as learner and the teacher as teacher, are the two initial and basic components. In this way, the developing of a sense of ownership puts emphasis on the outcomes of the CPD. In this sense, sense of ownership basically equates with the gaining of self-efficacy. Nevertheless, Hofstein et al. (2012) advocate that, in addition to the ability to reflect on their practice, a sense of ownership can be identified based on a range of attributes (seen only as examples and not intended to be exhaustive). These are suggested as:

(a) The willingness to involve other teachers in school.
(b) The willingness to identify socio-scientific issues (to be developed) that has a local characteristics (e.g. an environmental-type issue) looking for a relevant issue.
(c) Identifying themselves with the development and implementation.
(d) Telling your students that you were involved in the development or adaptation of the module.
(e) The dissemination of modules among peers.
(f) Teachers make an attempt to bring items (artefacts) that eventually will provide evidence for their classroom behaviour and practice.
(g) When teachers perceive that the topic or issue taught is relevant to his/her classroom (the nature of the students).
(h) When teachers decide to make changes, alternations, and amendment to the original module (based on their reflection).

These attributes are useful, but without extended evidence over time, they unfortunately do not indicate actual teacher ownership.

While teacher self-efficacy is extensively discussed in the literature, teacher ownership is a concept, which is not commonly used. Most authors tend to refer to a sense of ownership seeing this as self-efficacy (Hofstein et al., 2012). It is thus not really surprising that few researchers have attempted to see a measure of teacher ownership. Rannikmäe (2001) identified teacher ownership as a permanent change of behaviour and set out to measure this using a phenomenographic method. In this way she was able to undertake a qualitative approach in studying characteristics of variations (Marton, 1986).

3. METHODOLOGY

3.1. Design of the Research

This longitudinal study seeks to develop a CPD programme, based on identified teacher needs to determine teacher efficacy and further through a post-CPD follow-up, determine teacher ownership of proposed science teaching strategies, based on a philosophy designed to enhance students' scientific literacy. The study is designed in four stages:

(a) Planning a continuous professional development (CPD).
(b) Intervention based on an extended CPD programme.
(c) Determining the effectiveness of the CPD to develop science teachers' self-efficacy, based on teacher needs.
(d) Undertaking post-CPD action research, geared to promoting teacher ownership of the proposed philosophy and teaching strategy.

This is illustrated in table 2.

3.2. Samples

Three teacher samples were involved in obtaining data in this study. In stage 1 (planning the CPD programme) two different teacher samples were used.

The first sample consisted of 5 science teachers (sample 1), who were requested to provide feedback on the effectiveness of a previous continuous professional development programme, in which these teachers had participated during 2007–2008. This previous course had involved an intervention, involving teachers using 4 or 5, teaching modules, based on a 3-stage model design, which were taken from a European project (PARSEL) module databank (www.parsel.eu). All teachers who had participated in the above-mentioned project in Estonia were contacted and who continued to work at school was interviewed.

The second sample consisted of 27 voluntary science teachers (sample 2). These teachers participated in stage one by completing a pre-teacher needs questionnaire (TNQ) and also in stage two by participating in the CPD programme and also completing a post-TNQ. These teachers possessed the following subject specialisations: biology (9), science (10), chemistry (7), and physics (1). This purposive sample was composed of female (26) and male (1) teachers, of which 22 taught in high schools (grades 7–12) and 5 in middle schools (grades 5–9); 14 had less than, and 13 had over, 21 years of experience.

The third sample consisted of 10 science teachers (sample 3) who had previously participated in the stage 2 CPD programme and who wished to continue undertaking in action research (stage 3) by creating and using science modules, based on the 'education through science' philosophy and utilising the 3-stage model, and in a determination of levels of teacher ownership follow-up study (stage 4).

Table 2. Overview of the Study

Attribute	**Stage 1 Planning the CPD programme**	**Stage 2 Enacted CPD programme**	**Stage 3 Action research – post CPD**	**Stage 4 Teacher Ownership Evaluation**
Timeline	2010–2011	2011–2012	2012–2014	2015
Sample	Sample 1: 5 science teachers. Sample 2: 27 science teachers.	Sample 2: 27 science teachers.	Sample 3: 10 science teachers (sub-set of the 27).	Sample 3: 10 science teachers.
Derived approach	Establish Teacher CPD needs and design the CPD programme.	Conduct the CPD programme and determine the CPD programme effectiveness in terms of increased self-efficacy and reduced teacher needs.	Facilitating the teacher creation of teaching/ learning materials through action research and enabling teachers to further conceptualise the intended philosophy and teaching approach.	Identify levels of teacher ownership of the proposed science education philosophy and related 3 stage teaching strategy.
Data Collected	CPD inputs through semi-structured interviews with 5 teachers and use of a Pre-intervention teacher needs questionnaire (TNQ) (27 teachers) and focus group interview.	Post-intervention TNQ (27 teachers), Semi-structured interviews with 25 of the 27 teachers.	Teacher created modules (6); student feedback (108).	Semi-structured interviews with 10 teachers (plus portfolios).
Data analysis	Content analysis Wilcoxon Mean Rank test	Content analysis, Wilcoxon Mean Rank test and K-means cluster analysis.	Content analysis.	Phenomenographic analysis.
RQ and paper published	RQ 1, 2 Paper I, II	RQ 3, Paper III, IV	RQ 4, (Submitted)	RQ 4, (Submitted)

All 10 teachers had more than fifteen years of teaching experience. Two of the teachers taught only biology, two taught chemistry and six taught two different science subjects. Four of them taught at the middle school level (grades 7–9) and six at high school (grades 9–12).

3.3. Instruments

In this study used semi-structured interviews, focus group interview, Teacher Needs Questionnaire. Semi-structured interviews were carried out in stages 1, 2 and 4. In stage 1 we used semi-structured interviews were used for planning the CPD programme, in stage 2 for measuring the CPD programme effectiveness and in stage 4 for identifying teachers' level of ownership of conceptualise 'education through science' philosophy and teaching approach. TNQ was used in stage 1 and stage 2. Focus group interview was used in stage 1 after the answering to TNQ for validation of the outcomes the TNQ.

3.3.1. Stage 1 Interviews

The semi-structured questions used for the interview with the 5 teachers comprised of 18 questions in the following three domains: practical usage of the three-stage model, teaching style, and questions regarding the previous training programme (Paper I). For the CPD planning, the last block of questions was taken to be particularly relevant (Research question 1). These are detailed below:

1) Did you think the intervention study in which you were involved was a useful CPD model to offer to others?
2) What do you recommend to change within the CPD programme you experienced?
3) Where did you feel it was important to place greater emphasis?
4) Did you experience any obstacles, which stopped or limited your use of modules? *(Where the response was positive, this was followed up by the question – How did you strive to overcome those?)*

3.3.2. Stage 2 Interviews

Semi-structured interviews were used on two occasions.

I. The first semi-structured interviews were carried out with 25 teachers after the fourth CPD session to determine teachers' opinions about the usefulness of the CPD (Paper III, research question 2). The following question was asked:

What aspect of the CPD programme helped you the most to understand and embrace the 3-stage model in the classroom?

The semi-structured interviews were undertaken individually with 25 teachers, each taking about 15 minutes. The interviews were conducted on two consecutive days under similar conditions.

II. The second semi-structured interviews were carried out with 27 teachers in the last CPD session (Paper IV, research question 3). The teacher response to the semi-structured interview questions were used for triangulation against self-confidence clusters created based on a teacher needs questionnaire (TNQ) data. The follow questions (in italic) and where appropriate the follow-up, non-italic questions, were asked.

1) *How did you motivate students?* Do you think you did well? What would you do differently another time? (This was asked related to the implementation of stage 1 in the teaching approach).
2) *How did you undertake inquiry-based teaching*? What do you think went well in your implementation of inquiry-based teaching? What problems did you face and what would you do differently next time? Please give explanations? (This was asked related to the teaching of the 2nd stage).
3) *How did you carry out the decision-making on the 3-stage model*? What do you think went well? What problems did you encounter and what would you do differently another time? Explain? (This was asked related to the teaching of the last stage in the 3-stage model).

3.3.3. Stage 4 Interviews

Semi-structured interviews were carried out with the ten teachers to evaluate the teacher's level of ownership of the promoted 'education through science' philosophy (Paper V, research question 4). Prior to the interview, teachers were asked to choose one of the recent topics they had taught and create a portfolio in which they were asked to include lesson plans, samples of students' work, reflections on their own teaching and recommendations for future developments. Submission of the portfolio was followed by semi-structured interviews, in which the teachers indicated how they established a motivational scenario leading to inquiry-based science education (IBSE), involving students in meaningful socio-scientific argumentation and reflecting on issues, concerns and difficulties. The following question was asked: *How did you teach one of the latest topics?*

Where a deeper understanding of the responses was needed, additional questions were asked, such as:

(a) *How did you motivate students?*
(b) *How did you use inquiry teaching?*
(c) *How did you use decision making at the end of theme?*
(d) *What were the goals for teaching the module?*
(e) *What was viewed as the main gain from the earlier CPD programme?*

A phenomenographic approach (Akerlind, 2012; Marton & Booth, 1997; Marton & Pong, 2005) was used to identify the levels and major characteristics of teacher ownership derived from the portfolios and interviews.

3.3.4. Teacher Needs Questionnaire (TNQ)

Teacher Needs Questionnaire was used in stage 1 (Research question 2) and 2 (Research question 3). Paper II indicates that the Teacher Needs Questionnaire (TNQ) was devised through the following 3-step process:

Step 1 was an extensive review of theories and research related to teacher development, an examination of Estonian curriculum changes and identification of aspects associated with a motivational approach to the development of teaching-learning material. This step was based on an analysis of relevant literature and was undertaken to maximise the content validity of the TNQ, thus ensuring a sound theoretical framework (see theoretical background).

Step 2 involved writing individual items within subscales. Initially 92 items were identified, but on further validation by four experts from Tartu University, the number of items was reduced to 52, in these theoretical derived 10 subscales.

In Step 3, six experienced science teachers were asked to assess the comprehensibility, clarity and suitability of items.

The teachers evaluated each item and indicated whether the items were meaningfully representative of the corresponding subscales and whether they felt that the items were suitable and relevant; proposing, if appropriate, additional items. Items were modified based on these reviews. The final 52 item questionnaire, developed, piloted and validated by experts as a pre-post instrument, covered was administered to volunteer teachers willing to participate in the CPD programme (N=27).

The participating teachers were asked to separately rate their competence in terms of self-confidence (*Cronbach* α = 0.95) and their professional training needs, i.e. whether they would like to receive training in this area, (*Cronbach* α = 0.98) using a four-point scale (1–not at all; 4–definitely). Each of the 27 teachers responded to all items. Table 3 gives examples of items from every sub-scale and reliability of each sub-scale.

TNQ was used as pre- and post-instrument before and after the CPD programme. Outcomes from the validated teacher needs questionnaire (pre-TNQ) were used to plan the width and degree of emphasis in the CPD and measuring the effectiveness of enacted CPD programme (post-TNQ).

Table 3. Reliability of Teacher Needs Questionnaire

Sub-scale *Example of items*	**Self-confidence** *Cronbach α*	**Self-perceived training needs** *Cronbach α*
Nature of Science *Explain to students the difference between science and pseudo-science.*	0.74	0.82
Science and Technological Literacy *Refer students to a creative and well-reasoned approach to resolving social dimensions associated with scientific problems.*	0.73	0.71
Goals of Education *Specify the competencies that are suited to science teaching based on the context of science.*	0.56	0.79
Inquiry-based Teaching *Guide students to put forward scientific questions and hypothesis for investigation.*	0.57	0.78
Classroom Learning Environment *Redirecting admit students to ask questions and discuss the social dimension of scientific problems.*	0.84	0.94
Student Motivation *Determine relevant topics, in the eyes of students.*	0.72	0.89
Assessment *Undertake a range of formative assessment strategies with one`s own students.*	0.78	0.90
Theories of Education *Give meaning to zone of proximal development.*	0.87	0.94
Self-reflection *Carry out action research to raise effectiveness for my teaching.*	0.59	0.88
Inter-disciplinary *Associate with new approaches to teaching science.*	0.78	0.85

3.4. Data Collection

3.4.1. Stage 1

Data collection in stage 1 took place in two steps, during the period November 2010 – May 2011. Data collected from the semi-structured interviews (Paper I, research question 1) conducted on two consecutive days under similar conditions, were recorded and transcribed. Three teachers from the five were approached a second time, by telephone, to validate their answers.

Three months before the start of the CPD programme was carried out, the TNQ (pre-questionnaire) was administered by Internet with the 27 teachers who voluntarily participated (Paper II, research question 2). Each of the 27 teachers responded to all items.

3.4.2. Stage 2

Data collection in stage 2 took place in the period August 2011 – June 2012 (Paper III and IV, research question 3). The first semi-structured interviews (April 2012) were carried out with 25 teachers after the fourth CPD session to determine teachers' opinion about the usefulness of the CPD programme. Each interview took about 15 minutes and was conducted on two consecutive days under similar conditions. The interviews were recorded and transcribed.

The second semi-structured interviews (June 2012) were carried out with 27 teachers in the last CPD session. All answers were recorded and transcribed. Two researchers, against a literature-based reflection frame with an 80% agreement, categorized teacher's answers. The teacher responses to the semi-structured interview questions were used for triangulation against self-confidence clusters created, based on post-TNQ data.

After the CPD programme (in June 2012) the TNQ (post-questionnaire) was again administered by Internet to the 27 teachers who participated in the CPD programme.

3.4.3. Stage 3

Data collection in stage 3 took place in September 2012 – January 2014. Ten teachers created six modules within a participatory action research approach (Eilks & Ralle, 2002; Mamlok-Naaman, Rauch, Markic, & Fernandez, 2013). All ten teachers were motivated to create modules based on the 3-stage model and investigate how the modules influenced students learning. The action research lasted 1.5 years, with four regular meetings between the ten teachers and the researcher over this period. The meetings involved creating new modules, designing module implementation in the classroom, and also planning teacher collected students' feedback about the modules. During the meetings, a student feedback instrument was collectively created and piloted (with small group of students and teachers). All teachers collected and analysed the data.

Based on this data, one-exemplar case study was published (Vitsut, Valdmann, & Holbrook, 2014). Teachers created the modules individually or collaboratively, with or without scaffolding by the researcher. The modules were discussed during the meetings and assistance in offering ideas and making modifications provided. After the third meeting, the teachers used their own modules in the classroom and collected feedback from students (September – November 2013). Based on the feedback, modifications were made to modules, and for the fourth meeting all modules were formalized and shared with each other (December 2013 – January 2014).

3.4.4. Stage 4

Data collection for stage 4 took place in January 2015 (Research question 4) during a two days meeting. The teachers were asked to choose one of the recent topics they had taught and create a portfolio in which they were asked to include lesson plans, samples of students' work, reflections on their own teaching and recommendations for future developments. Submission of the portfolio was followed by semi-structured interviews, in which the teachers indicated how they established a motivational scenario leading to IBSE, involving students in meaningful socio-scientific argumentation and reflecting on issues, concerns and difficulties in the latest topic. Semi-structured interviews were recorded and transcribed.

3.5. Data Analysis

In current study used quantitative and qualitative methods to investigate the effectiveness of a planned CPD programme and the levels of science teacher's ownership of the 'education through science' philosophy enacted through a 3 stage teaching approach.

3.5.1. Quantitative Data

The teacher needs questionnaire (TNQ) analyses were undertaken using: mean scores, standard deviations, mean differences (calculated using Wilcoxon Mean Rank test), clustering (calculated using K-means) and effect size for eliminating the sample size influence on the findings.

Pre-TNQ mean scores, standard deviations, mean a difference between self-perceived confidences and training needs was calculated to identify teacher needs for CPD programme (Paper II, research question 2).

Pre- and post-TNQ were analysed using K-means clustering, to identify changes in self-confidence (Paper IV, research question 3); mean differences calculated to identify CPD effectiveness (Paper III, research question 3). K-means cluster provides a description of the characteristics that are the basis of grouping, indicating to which cluster someone belongs. The selected basis for the K-means clustering was the self-confidence scale, because the pre-TNQ and interview data (Paper II) show that self-perceived training needs are influenced by society's demands and teachers' personal interest. The initial hypothesis was that if a teacher has high self-confidence with regard to the claim, the self-perceived training needs are expected to be low. The hypothesis was not confirmed and the data of the interviews suggests that the training needs are heavily influenced by the demands of society (curriculum requirements), as well as by some teachers simply being curious (they are always ready to supplement themselves).

3.5.2. Qualitative Data

Semi-structured interviews (Patton, 2002) were transcribed. For analysing the semi-structured interviews, content analysis (Weber, 1990) was used (Paper I research question 1 and Paper III, IV research question 3) to identify CPD needs and effectiveness. Phenomenographic data analysis was used to identify ownership categories of the 'education through science' philosophy (Paper V, research question 4).

To identify teachers' reflection levels content analysis was used based on a literature-based reflection frame (table 4).

A literature-based reflection frame was created to capture teacher comments for each of the three model stages from using the teaching modules. This frame was based on the 4 levels (Larrivee, 2008; Smyth, 1989) as given in the table. Comments made by the teachers were applied to this reflection frame in relation to:

(a) Reflection for action (the reflection self-reported by teachers during the interview on their prior preparation).
(b) Reflection in action (reflections with respect to the actual teaching as it took place).
(c) Reflection on action (reflecting with respect to the future) (Killion & Todnem, 1991; Schön, 1983).

All reflective comments from the semi-structured interviews were analysed using frame in table 4. Similar explanatory expressions were linked together and preliminary levels (L1 – L4) of descriptions were formed, based on their differences. Simultaneous vertical analysis allowed identifying the types of reflections (R1 – R3), which is the aspects that became the focus when reflecting before, during, or with respect to future, teaching. Eventually reflections were divided into twelve categories, based on table 4. These responses were compared and discussed to ensure their mutual understanding.

The levels and types of reflections by teachers were grouped, based on the clustering of teachers to allow the manner of reflections to relate to self-confidence teacher clusters. Comments were inserted per teacher wherever the appropriate comments were made. By combining the reflection levels and types, teacher reflection categories were obtained.

Table 4. A Literature-based Reflection Frame Used for Analysing Teacher's Semi-structured Interview Responses (Paper IV)

	Guidelines for Reflective Comments / **Reflective Comments at a Productive Level** (Fund, 2010; Davis, 2006)			
Levels of reflection **Types of reflection**	Describing comments (L1) *Answering to the question:*	Effectiveness comments (L2) *Answering to the question:*	Problems remaining (L3) *Answering to the question:*	Future considerations (solution) (L4) *Answering to the question:*
Reflection-in-action (R1) component With respect to Stage: 1 2 3	What was I doing (at this time)? (L1R1) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	Was I feeling it was going to work (at this time)? (Perceived student reaction) (L2R1) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	Was I feeling there was going to be problems (at this time)? (Difficulties perceived) (L3R1) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	How was I thinking the problem could be reconciled? (L4R1) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*
Reflection-on-action (R2) component With respect to Stage: 1 2 3	What did I do before? (L1R2) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	Did it work in the past? (L2R2) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	What were the problem(s) I faced? (L3R2) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	How to reconcile the problems for the future? (L4R2) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*
Reflection-for-action (R3) component With respect to Stage: 1 2 3	What will I do in the future? (L1R3) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	How will I know whether it works in the future? (L2R3) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	What issues might I still face? (L3R3) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*	How do I suggest to other teachers how to reconcile future problems? (L4R3) *Re Q1 outcomes* *Re Q2 outcomes* *Re Q3 outcomes*

A phenomenographic approach was used for analysing semi-structured interviews transcript and portfolios on teachers' ways of understanding science teaching in general. First, each transcript was read several times by two independent researchers, seeking to detect similarities and differences in expressions. These independent findings were compared and discussed to ensure mutual understanding. Similar quotations were brought together and from the compilations, preliminary categories of descriptions were formed, based on their differences (Marton, 1986). The hierarchical nature of the categories was established as one of the leading principles in the analysis by:

(a) Seeking a descriptor or descriptors from the teacher transcripts where components were mutually exclusive.
(b) From the descriptor(s), the most meaningful set of hierarchical categories was/were selected.
(c) From (2), the numbers of categories were determined.
(d) Then, through a horizontal analysis, identification of the components (as variables) was determined, which allowed hierarchical categories.
(e) Following Akerlind (2012), the categories and dimensions of variation were rearranged, until they formed the final set of clearly identifiable categories and dimensions.
(f) The identified variables and categories were verified using expert opinion.

3.6. Validity and Reliability

In current study we used two types of instruments: questionnaire and interviews. The validity (content and construct) and reliability of the instruments and methodology used were determined as shown in table 4.

Validity is the extent to which an instrument measures what it is supposed to measure and performs as it is designed to perform. Content validity refers to the appropriateness of the content of an instrument. In other words, do the measures accurately assess what you want to know? In the current study, the expert opinion method was used. Construct validity refers to the degree to which inferences can legitimately be made from the operationalisations in study to the theoretical constructs on which those operationalisations were based. In the current study, we asked six teachers to evaluate the comprehensibility, clarity and suitability the items of TNQ. In the case of interviews, if necessary, we tried again to telephone teachers to make sure our interpretations coincided with the teachers' answers.

Reliability characterises the stability, consistency and suitability of the methodology used. In the current study, *Cronbach's alpha* is used, in case of TNQ, as an indicator of internal consistency to assess to what extent questions measuring the same phenomena coincide. All interviews were conducted under similar conditions, it is important for each interviewee to understand the question in same way, allowing sufficient time for formulating the answer. All answers were recorded.

In current study the attention was paid to methodological triangulation, which involves using more than one kind of method to study a phenomenon. It has been found to be beneficial in providing confirmation of findings, more comprehensive data, increased validity and enhanced understanding of studied phenomena (Cohen, Manion, & Morrison, 2007). In stage 1 to identify teacher needs we used semi-structured interviews with 5 teachers and TNQ with 27 teachers. In stage 2 to measuring the CPD programme effectiveness we used TNQ outcomes (used different data analyses methods), semi-structured interviews with 25 teachers after third session and with 27 teachers during the last session.

Table 5. Validation and Reliability of Instruments Used in This Study

Instrument	Validity/ reliability	Validation/reliability method used
Teacher Needs Questionnaire (TNQ)	Content validity	Expert opinion: Four experts from the University of Tartu and six experienced science teachers were asked to assess the comprehensibility, clarity and suitability of items. Items were modified as necessary.
	Construct validity	Analysis of relevant literature, theories and research related to teacher development, an examination of Estonian curriculum changes and identification of aspects associated with a motivational approach to the development of teaching-learning materials. Piloting TNQ with six science teachers, were asked to assess them the comprehensibility, clarity and suitability of the items.
	Reliability	*Cronbach alpha* determined for two components: Self-confidence scale $\alpha = 0.95$; Self-perceived training need scale $\alpha = 0.98$.
All semi-structured interviews	Content validity	Expert opinion: two independent researchers validated the interpretation of the interview outcomes.
	Construct validity	In case of need, teachers were approached a second time by telephone to validate their answers.
	Reliability	All interviews were conducted under similar conditions, allowing sufficient time for respondents to record their responses.

4. FINDINGS AND INTERPRETATION

4.1. Planning and Operating the CPD Programme

The feedback, from the 5 teachers, who had previously participated in an in-service teacher-training course (PARSEL project) and used 3-stage model teaching materials in their teaching, with respect to planning a new CPD programme, indicated the need to include following (Paper I, research question 1):

(a) Go through a module collectively to develop better understanding (and gain practical experience before teaching a class) (cited by 5 teachers); ‘playing through’ the 3 stage modules (cited by 2 teachers).
(b) Including presentations from specialists in the field of psychology and science in the training programme (cited by 3 teachers).
(c) Carry out the training over a longer period and establish a cooperative network for teachers (cited by 4 teachers).
(d) Explore possibilities for sharing experiences among those on the CPD programme (cited by 5 teachers).
(e) Provide more explanation of the module assessment guide (the earlier version was perceived as too complex) (cited by 5 teachers).

From analysing the outcomes for the teacher needs questionnaire the mean and standard deviations with respect to self-confidence and self-perceived training needs were found to be as indicated in table 6.

Table 6. Univariate Means, Standard Deviation and Mean Differences Between the Two TNQ Sub-components (N= 27) from the Pre-test (Paper II)

Sub-scale	**Self-confidence**		**Self-perceived training need**		**Significance of Difference**
	Mean	SD	Mean	SD	Z
Assessment	2.56	0.44	3.39	0.59	–3.935**
Classroom Learning Environment	2.95	0.34	3.20	0.54	–1.766
Goals of Education	2.84	0.44	3.25	0.57	–2.421*
Inquiry based Learning	2.72	0.39	3.47	0.59	–3.891**
Interdisciplinary	3.15	0.48	3.46	0.62	–1.797
Motivation	3.01	0.39	3.41	0.52	–2.535**
Nature of Science	2.98	0.37	3.20	0.51	–1.958*
Scientific-Technological Literacy	3.01	0.38	3.41	0.43	–3.118**
Self-reflection	2.50	0.42	3.30	0.67	–3.608**
Theories of Education	2.28	0.48	3.42	0.59	–4.272**

*$p \leq .05$, **$p \leq .001$

The significance of difference in the mean values was taken to indicate valid components for an effective CPD programme. These were identified to be:

(a) Assessment (Z= –3.935).
(b) Inquiry based Learning (Z= –2.891).
(c) Scientific-Technological Literacy (Z= –3.118).
(d) Self-reflection (Z= –3.608).
(e) Theories of Education (Z= –4.272).

CPD programme was designed using a constructivist sociocultural professional model (CSPM) (Howe & Stubbs, 1997) (table 7), taking account Bandura (1997) self-efficacy four determinants (table 8) and focused on identified teacher needs and the development of the 'teacher as learner', 'teacher as teacher' and 'teacher as reflective practitioner'.

As indicated in the literature, the CSPM model has the advantage that it promotes self-efficacy (Bandura, 1997), enables a supportive social context and supports teacher learning through their investigation and meaningful engagement. Table 7 gives an overview, showing how CSPM ideas were used in planning the CPD programme.

Table 7. CPD Design, based on CSPM

CSPM (Brand & Moore, 2010; Howe & Stubbs, 1996)	**Planned Activities within the CPD**
Involvement of teachers in planning and decision-making from the onset.	Taking account of teachers' recommendations from the semi structured interviews with the 5 and the 27 teachers.
Understanding of the world as connected to knowledge of themselves and their experiences.	Identifying and taking account of teacher needs (self-identified needs were solicited through the TNQ).
Teachers learn through their investigation and meaningful engagement.	Working through exemplary teacher/learning materials within the CPD sessions and guiding teachers to use teaching/learning materials in their classroom plus presentations in the CPD.
Teachers construct their knowledge in a supportive social context, with time for reflection and revision.	After the use of teaching/learning materials in the classroom, teachers reflect on their experiences present this in next CPD session, with discussion, to other participants.

The CPD design focuses on developing self-efficacy through taking account of Bandura's four self-efficacy determinants. Table 8 gives an overview showing how self-efficacy determinants are used in planning the CPD programme.

Table 8. Incorporating Self-efficacy Determinants within the CPD Model

Self-efficacy Determinants (Bandura, 1997)	Planned Activities within the CPD
Vicarious experience	By playing through the 3-stage module within the CPD seminar, teachers observe how the teacher-trainer is using the new teaching/learning materials; the teachers took on the role of the student and the teacher trainer's role was as a teacher, and all module played through as within a school setting.
Enacting mastery experience	Gained from an individual`s performance, how to use the new teaching/learning materials (3-stage modules used four times) in the classroom. Intervention in the classroom is a part of the CPD.
Social and verbal persuasion	Sharing best practice. Teachers, who used the same module in teaching, worked in small groups and discussed what went well and what could be changed. A group presentation was presented to others, in the CPD seminars; to share experiences and encourage others to use this module. Positive feedback was received from teacher trainers and peers.
Physiological and affective states	Supportive environment. Teachers and teacher educators were equal, no ideas were dropped, everyone was encouraged to express their opinions; for problems encountered in teaching, attempts were made to find solutions in group work, improving physical and emotional well-being and reducing negative emotional states; use of website and individual support encouraged.

The planned CPD structure was based on findings from a previously administered, teacher needs questionnaire (TNQ) and encompassed:

(a) Paying attention to an identified lack of confidence and competence in four TNQ subscales (inquiry-based learning (IBL); assessment; reflection, and theories of education) (Paper II).

(b) Introducing the philosophy of 'education through science' (EtS) and a 3-stage model (Holbrook & Rannikmäe, 2010) and working through the modules.

The CPD sessions were sequenced and spread across the school year, included 40 hours face-to-face contact time. The CPD programme initially focused on a practical demonstration of activities in which experienced teachers could see how lessons unfold when used the 3-stage model and how role-playing by participants could enable them to gain valuable vicarious experience. The small group discussions after the role-play supported teachers in linking their past experiences with the new ideas and led to later discussions with the teacher trainer and the whole group, following a CSPM design. An intended theoretical outcome from the initial session was that teachers conceptualised the ideas behind EtS and 3-stage model. In each seminar we introduced four modules, in total introduced sixteen modules (Appendix). Each teacher was expected to try out at least four modules during the academic year (one after each session) and to provide written feedback. The purpose of repeatedly trying out modules in the classroom situation was to give teachers valuable mastery experience.

And subsequent seminars were important for teacher professional interactions and sharing best practice and other key CSPM components such as self-reflection (in-action and on-action) (Schön, 1983) and analysing how to make the teaching-learning materials relevant for students. By encouraging teachers to support each other with ideas and tips, proposals for solutions to overcome problems (CSPM) and the teacher trainer overseeing, the shared recognition and problem solving, this enhanced teachers' self-efficacy through social and verbal persuasion (Bandura, 1997).

Changes were made to the CPD programme from the original plan (see Paper II), taking note of feedback received from teachers. For example, the CPD was planned as 4 sessions, two of which lasted for 2 days. However, after the third CPD session, it was found that, in general, teachers had difficulties in understanding the meaning and classroom operation of inquiry-based learning (IBL) and how it was possible to meaningfully motivate and assess students during the teaching of the modules without resorting to written tests. With this in mind, an extra session was included and three additional seminars (on IBL, assessment and student motivation), each delivered to small groups, were included, plus guidelines on how to create new modules (developing a motivational scenario and creating flowchart covering the use of the module). Feedback was obtained on the classroom interventions by means of written questionnaires completed by teachers and their students, teachers' power point presentations (a summary of the work of a specific module) as well as discussions in small groups. The inputs to the CPD were as illustrated in figure 2.

For the initial sessions, the emphasis of the presentations was on content and pedagogical knowledge ('teacher as learner'), which were intended to answer the question: What to teach and emphasize? The involvement of 'teacher as learner' was undertaken by means of involving the teachers in attending interactive lectures and in role-play. An important component promoting 'teacher as learner' was the science lectures. Lecture presentations were also included to enhance an interdisciplinary science background as related to teaching modules used for driving intervention teaching-learning situation in the classroom between CPD sessions.

The purpose of role-play was to give teachers valuable vicarious experience (the teacher trainer acted as the teacher and the teachers monitored how the teacher trainer introduced the stage of the module operation). This provided the opportunity for teachers to feel themselves in the role of students carrying out all activities in the module.

After the role-play, teaching objectives were discussed and the importance of each stage of the 3-stage model within teaching was explained. The inclusion of small group discussions after the role-play was intended to support teachers in linking past experiences with the new ideas. This also fed later discussions with the professional development provider and the whole group, following a CSPM design. The modules were intended to be based on novel interdisciplinary content; each of the sessions, where the introduction of the following new modules was accompanied by a corresponding subject interactive lecture.

Each session included: Continuous presentations and discussions on new modules, sharing best practice and reflections on classroom experience (teachers discuss the implementation of modules following CPD sessions after classroom practice).

Session 1	**Session 2**	**Session 3**	**Session 4**	**Session 5**
Main Themes (a) Education through Science; (b) Scientific and Technological Literacy (STL); (c) 3-stage model; (d) Role-play (modules).	*Main Themes* (a) Theories of education. (b) Inquiry-based Learning (IBL).	*Main Themes* (a) Assessment.	*Main Themes* (a) Assessment (b) Inquiry-based Learning (IBL)	*Main Themes* (a) Motivation (b) Creating a teaching flowchart for new modules

Between the sessions: Intervention in the classroom occurs between CPD sessions, with feedback questionnaires for students. Teachers had possibility to use of website and individual support.

Presentation structure:
The emphasis on:

Teacher as learner decreased from	50% 1st session to 0% last session
Teacher as teacher increased slightly from	45% 1st session to 50% last session
Teacher as reflective practitioner increased from	5% 1st session to 50% last session

Figure 2. Operating the CPD Model Based on the Identified Teacher Needs

In subsequent sessions, the emphasis shifted to ‘teacher as teacher’ (How to teach?) and to ‘teacher as reflective practitioner’ (Why I teach this way?). The ‘teacher as teacher’ was included through a workshop mode, where teachers were involved in various group activities, such as discussion of new modules, undertaking the development of motivational scenarios, carrying out practical work and reflecting on the assessment strategy. Promoting the ‘teacher as an effective teacher’ included equipping teachers with pedagogical content knowledge (PCK) aspects, such as contemporary student-centred, constructivist teaching methods; using an IBSE approach; appreciating relativist NOS; creating a classroom environment for stronger motivation; and ensuring science was taught so as to be seen as relevant for both boys and girls. In the design of CPD programme, these aspects were enacted in group work and seminars.

The promotion of the ‘teacher as a reflective practitioner’ was carried out by using teacher presentations, discussions and group work, where the teachers self-reflected on their teaching after trying out modules in the classroom situation. Creating the flowchart in small groups for a new module also supported the ‘teacher as a reflective practitioner’ component. The ‘teacher as a reflective practitioner’ involved developing teachers, individually and collectively, to evaluate their teaching by analysing the teaching of modules from the perspective of their impact on students’ intrinsic motivation, inquiry learning, and through cooperative/collaborative learning and assessment/feedback strategies. In the design of the CPD programme, these were promoted through teacher presentations and the sharing of practices within discussions.

The top arrow in figure 2 indicates activities that took place throughout the training period and the lower arrow indicates the continuity of actions between sessions and the interactions, which then followed in subsequent sessions. During the (2^{nd}, 3^{rd}, 4^{th} and 5^{th}) CPD sessions, teachers examined a module and reflected on its use in the classroom. Subsequently, teachers tried out a suitable module (one that fitted within the topic being taught) in their class.

4.2. Effectiveness of the CPD Programme

Table 9 show mean rating for teacher’s self-confidence and self-perceived training needs based on pre- and post-TNQ and the changes pre- to post CPD. Table 9 also shows that the effect size (*Cohen’s d*) is mainly greater than the standard deviation for both the pre- and post-TNQ components for most components, with the smallest effect size associated with the components, inter-disciplinary and motivation. The largest effect size was for theories of education and IBL.

The results given in table 9 indicate that teacher training needs decreased after the CPD programme in all ten subscale and significant mean differences between pre- and post-TNQ data were found in all subscales. The major significant mean differences between pre-and post TNQ outcomes based on self-confidence were in: goals of education, inquiry-based learning, classroom learning environment, and theories of education.

Table 9. Pre- and Post-TNQ Self-confidence (SC) and Perceived Training Needs (TN) Responses Determined in Terms of Effect Size (*Cohen's d*) and Significance of Differences (Wilcoxon Signed Rank Z Score) (Paper III)

	Sub-component	**Mean Pre-Q**	**SD Pre-Q**	**Mean Post-Q**	**SD Post-Q**	**Cohen's d**	**Significance of Difference Z**
Assessment	SC TN	2.56 3.39	0.44 0.59	2.85 2.76	0.41 0.58	0.68 1.08	–2.499 * –3.600**
Goals of education	SC TN	2.84 3.25	0.44 0.57	3.15 2.69	0.39 0.62	0.75 0.94	–2.886 ** –2.968*
Inquiry-based Learning (IBL)	SC TN	2.72 3.47	0.39 0.49	3.08 2.90	0.56 0.52	0.75 1.13	–3.051** –3.799**
Interdisciplinary	SC TN	3.15 3.46	0.48 0.62	3.26 2.93	0.54 0.63	0.22 0.85	–1.075 –3.277*
Classroom Learning Environment	SC TN	2.95 3.2	0.34 0.54	3.15 2.75	0.27 0.57	0.65 0.81	–3.132** –3.127*
Motivation	SC TN	3.01 3.41	0.39 0.52	3.12 2.96	0.25 0.54	0.34 0.85	–1.375 –3.101*
Nature of Science (NOS)	SC TN	2.98 3.20	0.37 0.51	3.16 2.73	0.33 0.46	0.51 0.97	–2.229 * –3.683**
Scientific-Technological Literacy (STL)	SC TN	3.01 3.41	0.38 0.43	3.21 2.83	0.32 0.55	0.60 1.17	–1.998* –3.739**
Self-reflection	SC TN	2.50 3.30	0.42 0.67	2.71 2.67	0.50 0.62	0.45 0.98	–2.116 * –3.605**
Theories of Education	SC TN	2.28 3.42	0.48 0.59	2.58 2.72	0.51 0.55	0.61 1.23	–3.294** –3.930**

*p ≤.05, **p ≤.001,
Response scale: 1 – not at all…4 – definitely
Key: SD – standard deviation, SC – self-confidence, TN – self-perceived training needs

To identify K-means clusters, the mean value for the 10 sub-scales for the self-confidence sub-component on the pre- and post-TNQ were utilised. This formed 3 clusters (representing high, medium and low self-confidence group to use a 3-stage model) (Paper IV table 3). 13 teachers moved to a higher self-confidence cluster on the post CPD K-means clustering, while 13 remained in the same cluster and one teacher dropped to a lower cluster. At the end of the CPD, the high self-confidence cluster group comprised ten teachers; the medium cluster fifteen and the lowest cluster consisted of two teachers.

Teachers' responses to the semi-structured interview questions were divided into categories of reflection based on a literature-based frame (table 4) and associated with self-confidence clusters (table 10).

Table10. Identification and Categorization of Teachers Based on Their Reflection Responses to the Various Stages in the 3-stage Model

Type of response	**Teaching stage**	**Describing comments (L1)**	**Effectiveness comments (L2)**	**Problems remaining (L3)**	**Future considerations (solution) (L4)**
Reflection-in-action (R1) component	1	(T27) **C3**	(T26) **C3**	(T8 T23) **C1, C2**	(T13) **C2**
	2	(T27) **C3**	(T26) **C3**	(T8 T23) **C1, C2**	(T13) **C2**
	3	(T27) **C3**	(T26) **C3**	(T13 T23) **C2**	(T8) **C1**
Reflection-in-action (R2) component	1	(T14, T18) **C2**	(T17, T21, T25) **C2**	(T3, T5, T7, T10, T11, T16) **C1, C2**	(T2, T9, T22) **C1, C2**
	2	(T11, T14) **C2**	(T18, T21) **C2**	(T3, T5, T7, T10, T17, T25) **C1, C2**	(T2, T9, T16, T22) **C1, C2**
	3	(T14, T18, T21) **C2**	(T3, T11, T17, T25) **C1, C2**	(T5, T10, T16) **C1, C2**	(T2, T9, T22) **C1, C2**
Reflection-on-action (R3) component	1	(T19, T24) **C2**	(T12, T20) **C2**	(T6, T15) **C1, C2**	(T1, T4) **C1**
	2	(T12) **C2**	(T19, T20, T24) **C2**	(T6, T15) **C1, C2**	(T1, T4) **C1**
	3	(T19, T24) **C2**	(T12, T15, T20) **C2**	(T6) **C1**	(T1, T4) **C1**

Key: T1 – T27 teacher identification (marked with numbers). Teacher category: **C1** – high self-confidence cluster; **C2** – medium self-confidence cluster; **C3** – low self-confidence cluster

Examples of teacher reflections that afforded the assigned category of reflection:

What am I doing? (L1R1**)** *"I am trying to make sure students recognise the familiar issue." C3*

Is it working? (Perceived student reaction) (L2R1) *"Students are seen to be more creative by looking for answers to unexpected experimental results." C2*

Is there a problem? (Difficulties perceived) **(L3R1***)* *"Students are unable to deal with planning inquiry independently and I helped them by asking questions." C2*

How do I reconcile the problem for the future? **(L4R1***)* *"Students have difficulties with deadlines. They do not conclude their inquiry in the allotted time. I think students' involvement in the drafting of the inquiry work plan is helpful in meeting teaching deadlines." C1*

What did I do? (L1R2) *"I used fragments of a movie for the scenario." C3*

Did it work? (L2R2) *"In general, reflective discussions during the experiment are seen as helpful in guiding students in being prepared for unexpected results in the future." C2*

What were the problem(s) I faced? (L3R2) *"I saw problem related to how much students learn from other group's presentations. It seems questionable how much the student presentation style and orientation offered learning to the other student groups." C1*

How I was dealing with past problems meaningful for the future? (L4R2) *"Since some student does not like to participate in the final discussions, I feel it is necessary to provide more encouragement and provide them with leading questions that help to develop the student's argumentation skills." C1*

What will I do in the future? (L1R3) *"Involve students more, as I recognise that students are more motivated to learn science when they are trying to determine answers to relevant social problems." C2*

How will I know whether it works? (L2R3) *"By giving more attention to teaching students how to evaluate information, I hope I can see whether students use sources that are appropriate." C2*

What issues might I still face? (L3R3) *"Determining how much effort is important in getting students to progress towards more open inquiry approaches." C1*

Only the high self-confident cluster group of teachers gave reflective comments in answer to the question: *How do I suggest other teacher advice to reconcile future problems* (L4R3) (table 4, 10)? They gave reflective comments related to all three teaching stages included within the modules which teachers used in the classroom (contextualisation, de-contextualisation and re-conceptualisation) (see Paper IV, Appendix 2).

Clearly all ten teachers were willing to adapt their teaching style and from reflections on how to deal with problems willing to embrace the 3-stage approach. These teachers commented that they wished to develop their own future teaching/learning modules and were willing to give advice to other teachers.

Teachers grouped in the medium self-confidence cluster were able to reflect on all three teaching stages. Two teachers in the medium self-confidence cluster had previous teaching experience in using modules based on the 3-stage approach (they previously participated in similar project) and perhaps not surprising, all comments at the level of 'future considerations' (L4R2; L4R1) (table 4, 10) were given by them. In general, teachers in this cluster gave meaningful, explanatory comments of their actions in the classroom, but showed far less reflection on the value of their actions compared to teachers in the high self-confidence cluster group.

Teachers from low self-confidence cluster gave fewer comments about their teaching and tended to simply provide feedback in the form of a description (L1) or in terms of the effectiveness of their teaching (L2). They never reflected on future action (reflection-for-action; R3) and did not really comment on stage three (the re-contextualisation stage in which the science gained I used to relate to the initial scenario) and finished with interpretation of findings (which is part of the 2nd stage).

The results of the semi-structured interviews related to the 25 teachers' assessment of the content and design of the training, the following key responses were obtained:

(a) Teachers indicated that role-play helped them understand the 3-stage model, reduced anxiety in face of the new and the unknown and raised self-confidence (cited by 18).

(b) Teachers found sharing best practices gave useful tips, as well as increasing self-confidence to make changes to modules, based on students' interest and local background (cited by 20).

(c) Participants found the inclusion of interdisciplinary lectures increased self-confidence to deal with the problems, related to both the chemistry and biology in a single module (cited by 15).

4.3. Teacher Ownership for the Proposed Teaching Strategies

Eilks and Ralle (2002) recommend participatory action research for creating and testing teaching-learning materials. Table 11 describes this approach in more detail in the case of the current research. The research is seeking to determine the degree of teacher ownership of the teachers involved, based as a first aspect in their ability to develop modules.

During the action research, teachers created 3-stage teaching modules, based on the 'education through science' philosophy. 6 modules were initiated, either by the teachers working individually or in groups.

Table 11. Stages of the Participatory Action Research

Stage of the Participatory Action Research (Eilks & Ralle, 2002)	**Description of the action taken within the current study**
Development of teaching-learning materials indicating stages and strategies	Selecting a topic and initiating the creation of a module (via a flowchart) at a first meeting. Introduce the draft module for whole group discussion. Create, collectively, a student feedback questionnaire (at a second meeting).
Testing in practice	Use the modules in the classroom setting.
Evaluation	Collecting student feedback. Analysing the student feedback.
Reflection and revision	Sharing the practice. At the third meeting, make modification to modules. Formulation and distribution of all modules to the group at the fourth meeting.

All modules were discussed by the group. The group developed the student feedback questionnaire collectively. Teachers taught one module when this meaningful fitted their teaching schedule. After teaching the module, feedback data was collected using the questionnaire. Each teacher analysed the feedback and made notes for later input into group discussion. The teachers discussed the outcomes of the teaching and reflected on modifications needed to the modules. Modifications were undertaken. The titles of the modules created are listed in table 12.

Table 12. Modules Created by Teachers and Feedback from Students

Module name	Number of teachers involved	Frequent Student comments on the module We liked this module because… (n=108)
Laundry.	3	There was more group work and experimental work; we were more involved in everyday life.
What type of food we need?	2	We got together to discuss and work together and think as one team (family), We were more independently able to investigate and substantiate opinions.
Water amazing role in society.	2	Experiments with discussion and a Round Table enabled us to argue. Team-work is good, because the opinions were put against those of a group of peers.
Becoming a landlord.	1	There was more discussion and analysis, enabling the consideration of the opinions of others.
A House in the Alps.	1	Less stress. It allowed time to delve into the topic and make it more memorable. Argue more. We talked about modern science and how it influences society.
Is fatigue a crime?	1	We were able to discuss in a more fun and creative manner. I liked the experiments, the drawing of conclusions; find out the causes and consequences.

Three teachers created modules individually, while seven teachers preferred to create modules collectively in small groups (2 or 3 teachers in group). As shown in table 12, students liked the 3-stage modules, because they were motivated to learn and they had an opportunity to actively investigate and possibilities to discuss and argue with peers.

One year late after the action research the teachers were asked to choose one of the recent topics they had taught and create a portfolio in which they were asked to include lesson plans, samples of students' work, reflections on their own teaching and recommendations for future developments. Submission of the portfolio was followed by semi-structured interviews. We utilized the phenomenographic research, in which we qualitatively investigate different ways teachers experience or understand an 'education through science' phenomenon.

Table 13. Frequencies of Teacher Responses for Identifying Ownership of the 'Education through Science' Philosophy

Frequencies of variation						
Reflection type led to distinctive ownership categories	**Moti-vation**	**Inquiry activities**	**Decision making**	**Purpose of teaching**	**Gains from in-service identified by teachers**	**Constraints**
Informing about effectiveness 2 Identifying/dealing with problems 2 Extended to include future considerations 2	SSI 2	Better conceptualize the science ideas and their interrelationship with socio-scientific issues within society 2	SSI+DM 2	Wide range of skills oriented included social and value judgment 2	Interdisciplinary knowledge and skills linked to science and society 2	Difficult to find relevant socio-scientific issue 2 Students' knowledge of the suffering 1
Informing about effectiveness 5 Identifying/dealing with problems 5	NLM 2 SSI 1 QEL 1 SQ1	Make learning interesting 3 Better conceptualize the science ideas 2	NS 1 SDM 3 SSI+DM 1	General skills oriented 4 Curriculum implementation 5	More knowledge about student's inquiry learning 4 New ideas 3	Time consuming 2 Students' knowledge of the suffering 3, teacher workload3 Lack of tool 2
Informing about effectiveness 3	QEL 1 NLM 1 SQ 1	Make learning attractive 3	NS 2 Describing 1	Curriculum implementation 2	New ideas 3	Time consuming 3 Curriculum demands 3 Lack of tool 2

Key to components expressed within a dimension of variation:
QEL – question from everyday life; NLM – new learning method; SQ – science question; SSI – socio-scientific issue; NS – new scenario; SDM – science decision making; SSI+DM socio-scientific decision making

Seven dimensions of variation were identified from the semi-structured interviews and review of the portfolios, labelled as: reflection type, student motivation, and inquiry activities, decision-making, purpose of teaching, identified by teachers' constraints, gains from in-service programme (table 13). The hierarchical nature of the categories was established as one of the leading principles in the analysis. The major dimension of variation, which led to distinctive categories, was the reflection type, giving descriptions for teachers at each ownership level, while the others dimensions only described some teacher categories. Based on this major dimension of variation three categories of ownership were found where ownership of 'education through science' philosophy and teaching approach was seen as paradigmatic, experiential and emotional.

The term – Emotional ownership is used to describe a sense of ownership which utilized operational elements of the 3-stage model, but which was not interpreted as per the intended philosophy and approach. They are assessing the success of teaching through own and students' emotions. They did not pay attention to reflecting on attitudes, values and learning outcomes.

The term – Experiential ownership was used to describe teacher who possessed the ability to use the intended approach as per a socio-scientific introduction to scientific learning and applying the science in a society situation. During reflection, they were able to identify problems and responded to questions about the theory, practice, assumptions, beliefs and values related to teaching. They were also able to reflect on student – teacher interactions, emphasising teacher actions, but did not pay attention to the value of the undertaking. Experiential ownership teachers used the 3-stage model in a rather narrow, compartmentalized way (i.e. how to motivate students, how to apply IBL (inquiry based learning), how to teach students to make a decision).

The term – Paradigmatic ownership was used to describe full ownership of the 'EtS' philosophy and in operationalizing a context-based approach as per the 3-stage teaching model. Teacher reflection is related to the meaning of teaching in an 'EtS' philosophical context and covers future considerations. The assessment by teacher took into account: values and attitudes, as well as subject skills and knowledge. All at this level possessed high self-efficacy as a result of a successful CPD induction and had reached a competent level in being able to create, independently, new teaching/learning, 'EtS' materials, based on the 3-stage model and to disseminate these at an international level.

Table 14 provides an overview of the results of the ten teachers' participation in the different stages of this study. Two teachers who created modules independently and attended an international conference with a presentation have accepted 'EtS' philosophy, which is described in this research as paradigmatic ownership.

Table 14. Background Information of the Teachers and Characterization During the CPD

Teacher	Subject	School type	After CPD programme (Stage 2)		Action research (Stage 3)		Evaluation (Stage 4)
			Self-confidence based on TNQ	Self -identified training needs based on TNQ	Mechanism for creating new EtS teaching/ learning materials based 3-stage context model	Dissemination enacted	Ownership level
T3	Chemistry Agronomy	High school	High	Low	Individually and independently	Article, presented at international level conference	Paradigmatic
T8	Science Biology Chemistry	Middle school	Medium	Medium	Individually and independently	Article, presented at international level conference	Paradigmatic
T1	Chemistry Health	High school	High	Low	Collaboration (with T2 and T9)	Regional level	Experiential
T2	Chemistry	High school	High	Low	Collaboration (with T1 and T9)	Regional level	Experiential
T4	Science Biology	Middle School	High	Low	Collaboration (with T6)	Conference (National level)	Experiential
T6	Science Physics	Middle school	Medium	Low	Collaboration (with T4)	Conference (National level)	Experiential
T7	Chemistry	High school	Medium	Medium	Alone and tutorial help	Regional level	Experiential
T9	Biology	High school	Medium	Low	Collaboration (with T1 and T2)	School level	Emotional
T10	Biology	Middle school	Low	Medium	Collaboration (with T5) and with tutorial help	School level	Emotional
T5	Chemistry	High school	Medium	Low	Collaboration (with T10) and with tutorial help	Regional level	Emotional

5. DISCUSSION

This study seeks to address science teacher's vision, operation and background needs by developing an effective continuous professional development (CPD) programme to raise teacher's self- efficacy and further determine teacher's levels of ownership of an identified philosophical approach to the teaching of science, seen as more appropriate to raising students' scientific and technological literacy and competences, as advocated in the Estonian National Curriculum (Estonian Government, 2014). In guiding teachers in this direction, this study recognises the importance of meaningful and effective (CPD) and initiates this research by seeking teacher needs before developing a CPD programme, covering the vision, operation and background needs as amplified in Paper II.

The study is designed, based on 4 steps, encouraging teacher to be involved in a post CPD follow-up, through a longitudinal study, during which teachers are involved in action research during their creation and utilisation of suitable teaching modules. The degree of teacher ownership is determined at the end of stage 4, using a phenomenographic approach.

5.1. Devising an Effective CPD Programme

Research has shown that continuous professional development (CPD) programmes can change teacher's beliefs and teaching styles (Hofstein et al., 2003; Bryan, 2012). This research recognises that an effective CPD programme is valuable in promoting teacher reflections (Howe & Stubbs, 1997, Kerstin et al., 2010; Moore-Russo & Wilsey, 2014) leading to teacher self-efficacy (Bandura, 1977). This is seen as essential for promoting a new vision of science education in line with the 'education through science' philosophy being promoted through this research and seen as being executed through a 3-stage approach.

To create a CPD programme, deemed to be meaningful and effective for teachers, two major considerations were taken into account within this research:

(a) Opinions were solicited, expressed through a semi-structured interview, by 5 teachers who had previous participated in a long term CPD programme. The CPD in which the 5 teachers had participated had similarities to the CPD being developed in this research (within step 2) (Paper I research question 1).

(b) The science education vision, operation and background, seen as necessary for teachers to achieve ownership of the promoted science education thrust designed to enhance students' STL and envisaged through a CPD programme for teachers.

Overall, the teacher comments were deemed valuable in planning the new CPD, taking into account that the teacher recommendations for future training was largely consistent with arguments put forward by Van Driel (2005), who recommended in planning new developments to refer to problems which teachers were currently experiencing and which were in line with a bottom-up approach (Blonder et al., 2008).

All 5 teachers indicated that teachers participating in the CPD programme would like to receive support through long-term training and recommended any new CPD programme should pay attention to this aspect. A number of researchers have pointed out that training programmes which last throughout the school year are more efficient than isolated, one or two-day programmes (Brand & Moore, 2011; Lumpe et al., 2000; NRC, 1996; Posnanski, 2002).

5.2 Using a Teacher Needs Questionnaire (TNQ) to Solicit Teacher CPD Needs

While the interviews with the 5 teachers gave meaningful insights into the type of CPD programme needed, it was seen as important to also consider the actual participants' needs. For this, a teacher needs questionnaire (TNQ) was devised and administered. The teacher needs were identified through a desire to raise their self-confidence and meet teacher desired CPD preferences, related to the development of science education expertise, as indicated in table 6. This very much related to the proposed vision, operational approach and educational back grounded needed, as identified in paper II. While paper II points out that teacher self-confidence and perceived training needs relate to a vision for science education and this can be ascertained through the 4, literature supported, discussion areas put forward in figure 1, i.e.

(a) Recognising the goals of science education.
(b) Enhancing students' science and technological literacy (as put forward as an intended target in the Estonian curriculum, 2014).
(c) Gaining an informed understanding of the nature of science, as it pertains to the teaching of science subjects in school.
(d) The value of promoting students' intrinsic motivation.

Clearly a further important consideration in promoting teacher's self-confidence is meeting teacher's operational needs. Figure 1 lists 6 components, further justified in Paper II, as – promoting the classroom learning environment, undertaking meaningful assessment, organizing inquiry-based teaching, utilizing inter-disciplinary teaching and seeing the importance of self-reflection skills. While the classroom learning environment is seen as of particular importance in enhancing student motivation, the stress, especially in stage 1 of the 3-stage model, is in students' intrinsic motivation, encouraging students to want to be involved in the learning (Cavas, 2011; Rannikmäe et al., 2010). The 5 interviewed teachers indicated the importance of guiding teaching in relation to both formative and summative assessment strategies, while proficiency in inquiry-based science teaching is important for student involvement in the proposed science learning approach, especially linking cognitive and experimental aspects (EC, 2007; Dudu & Vhurumuku, 2012; Knezek et al., 2013; Spronken-Smith et al., 2011); interdisciplinary science teaching is a further important area stressed in the literature in relating science to the society (Dillon, 2008; Mikser et al., 2008; Strathern, 2007). While paying attention to self-reflection skills as a component of a CPD programme is recognised as important in promoting teacher's self-confidence and in seeking teaching deficiencies, which need to be addressed (Bolte et al., 2012; Kaune, 2006).

The science education literature strongly advocates the promotion of relevant education theories to provide teachers with a meaningful background to promote the desired philosophy and a teaching approach, purposely arranged for this research into include three purposeful, interrelated and complementary stages, specified as: contextualisation, de-contextualisation and re-contextualisation (Holbrook & Rannikmäe, 2010). All stages are based on constructivist theories (Lutz, 1996), Maslow's theory of need (1943) and Self-determination theory (Ryan & Deci, 2002), with Activity theory (van Aalsvoort, 2004a; b; Rodrigues, Taveres, Ortega, & De Mattos, 2010; Roth & Lee, 2004) and the Zone of proximal development (Vygotsky, 1978) recognised as important in developing the approach in the 2nd stage.

The overall teacher needs questionnaire (TNQ) is compiled of 52 items covering the 10 sub-areas, validated within a European project involving 20 countries (Bolte et al., 2012). Table 6 shows that, across the 27 teachers, self-confidence was lower in 5 areas – expressing relevant educational theories related to science teaching, self-reflecting on science teaching, undertaking assessment, conceptualising inquiry-based learning and recognising the goals of education. Table 6 also showed that the 27 teachers indicated a higher average CPD need score, related to education theories, assessment, inquiry based learning, interdisciplinary and, not surprisingly when considering a new philosophical direction, promoting student motivation. Overlap occurs in the teacher responses for 3 of the 10 TNQ areas, across the areas to enhance self-confidence on the one hand and teacher identified needs on the other. These were thus taken as important topics to include in the CPD, alongside the important need to introduce the 'education through science' philosophy and the 3-stage teaching approach. These components were also seen as important to enhance students' science literacy, as indicated in the Estonian science curriculum (Estonian Government, 2014).

Also derived from table 6 is the significance of the difference between the self-confidence and needs scales. The significance is taken to indicate a need for the CPD to include education theories, assessment and inquiry-based learning, but also motivation and self-reflection. While the 'education through science' philosophy and the 3-stage teaching approach are clearly a major focus, providing for science teaching to enhance students' STL, a second session is put forward, devoted to coverage of identified education theories and the key component on inquiry-based teaching. A third CPD session is included, specifically devoted to assessment (in line with the interviewed teacher's comments and also the table 6 outcomes). However, the 4th session is a post-planning addition, based on the fact that the teachers requested more support related to inquiry-based learning (IBL) and Assessment during sessions 2 and 3. Even though the interviews with the 5 teachers show that attention, in the CPD, to assessment strategies is needed, the degree to which this is found to be problematic is greater than expected. The extra session elaborated formative assessment approaches showing these are important in guiding the student centred learning and easing time constraints if testing in a summative manner is overstressed. More surprising was the extra attention to inquiry-based learning, even though a European commission document (Science Education Now) was published in 2008 stressing the importance of inquiry-based teaching/learning and curriculum documents supported this approach (Estonian Government, 2014).

The 5th CPD session focuses on motivational ideas. Also included is teacher self-reflection seen as a feature in promoting teacher self-reporting in the workshops, where teachers presented their findings from trying out modules. As the 5 interview teachers suggest, teacher comments on this after the CPD programme, are strongly positive.

5.3. The CPD Programme and Its Effectiveness

The 40-hour CPD programme was designed, based on the identified teacher needs discussed above and promoted via a Constructivist Socio-Cultural Professional Model (CSPM) as advocated by Howe and Stubbs (1997). The CPD approach was based on promoting self-efficacy determinants (Bandura, 1977) recognising that teachers needed to be involved as a 'learner' (gaining new knowledge and experiences), also as a 'teacher' (gaining skills for classroom interaction for applying the 3 stage model) and finally as a 'reflective practitioner', (gaining from experiences in the actual teaching carried out in the classroom, or from the approach used by other teachers when giving their presentations within the CPD programme sessions).

The first CPD session was designed to give emphasis to upgrading science conceptual knowledge, in line with the earlier solicited teacher recommendations. This was purposely organised to stress that the CPD was about the learning of science and that teachers needed to possess self-confidence in teaching using the new approach. In this session, the weighting of time allocated to presentations was purposely made high (50%), with the rest of the time geared to 'playing through' a 3-stage teaching/learning module. The first session was also designed to focus on the 'education through science' philosophy and explanations of the 3-stage model. These were seen as providing the key content of the CPD programme. Also within this session was explaining to participants the intentions of the CPD, the manner in which it was organised to promote coverage of teacher needs and the inclusion of new science content pertaining to modules being presented.

The following sessions focused on the identified teacher needs, as explain earlier, to enhance teacher's self-efficacy in meaningfully promoting the 3-stage approach for intrinsically motivated, inquiry-based science teaching and learning. In later sessions, the CPD gradually placed more emphasis on teacher participation in groups, or in providing presentation feedback, as indicated in figure 2. This division of the time allocation was carefully planned in line with teacher suggestions, based on the interviews and TNQ outcomes.

In line with identifying teacher's self-efficacy, this study sought to measure the effectiveness of the CPD programme. This was based both on findings related to the change of emphasis in the pre- and post-TNQ and through teachers' semi-structured interviews during and after the CPD programme (Paper III, IV, research question 3).

Outcomes from the post-TNQ findings (table 9) indicated that the CPD was effective in raising teacher self-efficacy. This was based on the increase in teacher perceived self-confidence, plus teacher recognition that their perceived training needs had decreased. The mean effect size was positive, indicating a positive input from the CPD, which was especially noted in promoting the learning environment during the CPD sessions, an appreciation of the goals of education, the attention placed on explaining and giving examples of inquiry-based learning and recognition of the value of knowing about the theories of education elaborated during the CPD. While the importance of establishing a meaningful learning environment during teaching and recognition of the goals of education were not specifically addressed in the CPD, an emphasis on involving the teacher in a student-interaction consideration, linked to the establishment of a good classroom environment and the realisation of the purpose of teaching, was seen as playing a role in promoting gains in confidence in handling the suggested approach to science teaching advocated in the CPD.

Findings from the K-mean clustering analysis (Paper IV), seen as a useful approach to group the participating teachers based on their pre-post TNQ responses, support the effectiveness of the CPD argument. In total, 13 teachers moved to a higher self-confidence cluster within the post CPD K-means clustering, while a further 13 teachers remained in the same cluster with only one dropping to a lower cluster. The dropping was largely due to outside circumstance associated with a lack of support from the school headmaster.

A further measure of the effectiveness of the CPD was obtained from teacher reflections. Findings (Paper IV) suggest a strong correlation between the self-confidence clusters and levels of reflection practiced by the teachers as reported during the post-CPD teacher interviews, held during the last CPD session. In the interviews, the teachers were asked three questions, aimed at determining teachers' reflections on how they used the 3-stage modules in their classroom teaching. The interviews allowed teachers to reflect on the use of the different stages in the modules and the relationship between self-confidence and the teacher's reflection level (Paper IV). Findings suggested a strong correlation between teaching confidence gained from the CPD programme and the range of identified types of reflective feedback, based on classroom teaching in implementing the 3-stage, 'education through science' teaching/learning modules. As the CPD was planned and enacted using a constructivist, socio-cultural professional model (CSPM), suggested by Howe and Stubbs (1997), one key component strongly encouraged was teacher's self-reflection. As several researchers have highlighted (Clarke & Hollingsworth, 2002; Kaasila & Lauriala, 2010; Shulman, 1987), the importance of teacher reflection when experimenting with a new teaching approach during a professional development programme, which focused on changing teachers' beliefs and practices.

The results in examining the relationship between self-confidence and levels of reflection from this study clearly supported the opinion that reflection helped teachers to integrate the pedagogical theory and professional teaching-learning materials with their own experience, thereby developing their own practice. However, the teachers placed in the high and medium self-confidence clusters gave more productive reflective comments; their reflections were associated with personal experience, practical knowledge, and acceptance of educational theories and indicate professional development (Fund, 2010). These teachers took a positive position on the meaning of purposeful teaching, described through useful actions to undertake so as to change the situation (Smyth, 1989) and engaged in critical reflection about moral and ethical implementation associated with their teaching (Larrivee, 2008). These findings pointed to gains in estimates of the teacher's changed beliefs and practices. In this study, this was taken to indicate that the teachers believed that the 3-stage model and the related teaching modules were useful tools to increase students' scientific and technological literacy (Holbrook & Rannikmäe, 2007) and that the CPD programme was effective to raise teachers' self-efficacy in this direction.

The findings from the teacher reflections lend support to the opinion that the 'education through science' CPD model was an effective tool in raising teacher's self-efficacy to use inquiry-based learning (IBL). While this can be taken to be inconsistent with a previous study, in which Kask (2009) found that Estonian science teachers had low awareness and skills about inquiry based learning (IBL), the reason for this might be associated with the need for high self-confident teachers in seeking teacher change and that an effective CPD programme was needed to influence teaching reforms. Nevertheless, based on the teacher's reflections in this study, difficulties were still identifiable; for example, teachers indicated that students did have difficulties to create inquiry questions. However, the fact that the teachers noted such problems could be taken as indicating a heightened teacher confidence in seeing the value of promoting inquiry-based teaching. Also, the teacher reflections reported in this study seemed to indicate that teachers who had higher self-confidence confided more with their students and in agreement with Smith (2010) gave students greater autonomy to choose learning problem/task, leading to a greater teacher willingness to use open inquiry learning approaches.

All teachers indicated that they valued the scenario stage, included in each teaching module, from two major viewpoints: it was motivational for students and it was very usefulness for evaluating student's prior knowledge. This was very consistent with the intentions in the development of stage 1 within teaching modules using the 3-stage model approach (Holbrook & Rannikmäe, 2010). Research has showed that in any professional development programme there were components, which most teachers were able to pick up. Based on the literature, these tended to be the most novel aspects (Kaune, 2006), or aspects related to major paradigm shifts in education, well communicated with the public and therefore publicly valued (Holbrook, 2008a).

From this study, the science teachers indicated that the most difficult teaching aspect was the third (re-contextualisation) stage, where the aim was developing students' argumentation skills and decision-making techniques. The findings supported previous evidence that ethical dimensions were new and uncommon in science teaching (Jutunen & Aksela, 2014; Saunders & Rennie, 2013) and there was the necessity to create specific science education practices to improve student's argumentation and decision-making skills (Laius & Rannikmäe, 2011). This was also in agreement with previous findings (Paper I), where science teachers had difficulties with leading students' discussions and argumentation.

The findings from this study were seen as powerful indicators that in future (in professional development programmes and teaching/learning materials), more attention was needed in handling the third stage (re-contextualisation), especially for developing aspects indicated in the curriculum such as students' argumentation skills and decision-making techniques.

The semi-structured interviews after the fourth session were carried out with the purpose of evaluating the design and activities of the training (Paper III). Teachers considered that the opportunity to enact a module from start to finish and being involved in reflective group discussions to share best practice helped reduce concerns associated with, for the teachers, a novel teaching method. These sets of interviews were connected with the physiological and affective states of teachers related to moving to the 3-stage, 'education through science' approach, which Bandura named as one of the important components of self-efficacy beliefs. Enacting a module from start to finish provided an opportunity for teachers to monitor how the teacher trainers carried out the module; one way to gain vicarious experiences (Bandura, 1997). But this was more than simply observation; it involved active participation and practice-oriented comments. Both aspects (observation and stress reduction) were anticipated to create meaningful preconditions for teachers to obtain positive experiences when they implemented modules in their own classroom. Positive mastery experience was shown to be the most important factor to increasing teacher self-efficacy (Bandura, 1997). In fact, Ross and Bruce (2007) had similar outcomes when they took into account Bandura's four determinants of self-efficacy in undertaking a professional development programme and found these had a positive impact on teachers' ability to handle student management issues in the classroom.

The 'teacher as learner' aspect, included in the CPD, was seen as an important component. In this respect, it was not surprising that teachers placed emphasis on the value of the interdisciplinary knowledge gained. This was especially appreciated, because the teaching modules were seen as interdisciplinary and required extensive knowledge in different science fields (biology, chemistry, physics) in order for the teacher to feel confident and competent in the classroom. An issue teachers indicated they faced was that the natural sciences were evolving rapidly and it was difficult to keep in touch with modern scientific achievements. Lectures were seen as able to provide a quick review after which it was easier to work independently, making reading easier to understand and identify the direction in which to move forward. This was supported by literature finding; for example, Swars and Dooley (2010) indicated that a lack of science content knowledge in the wider socio-scientific focus could lead to a lowering of personal self-efficacy. Zeidler, Applebaum and Sadler (2011) argued that in order to internalize a shift from traditional classroom practice to a socio-scientific issue (SSI) framework, it was crucial for teachers to be comfortable with the content. This was strongly supported by previous research (Paper II), where teachers emphasised the need to include scientists and psychologist in professional development training.

The findings from this study were in line with earlier research, which highlighted several relevant aspects: that pedagogical development programmes needed to be active and practice-oriented (Day, 1999; Lee, 2000), reflective and collaborative (Clarke & Hollingsworth, 2002; King & Newman, 2001) and involving the sharing of best practices (McLaughlin & Talbert, 2001). Both reflection of one's own teaching and sharing best practice were part of the CPD plan to support teachers as teacher and teachers as reflective practitioners.

5.4. Action Research and Determining Teacher Ownership

After the completion of the CPD, 10 teachers agree to a follow up study involving them in creating and using modules in their teaching at school. These teachers were all from the top self-efficacy clusters, as determined using K cluster means analysis following the CPD. The approach was viewed as action research, through which the teachers were developing their ownership of the 'education through science' ideas (Research question 4).

Within this aspect of the study, the 10 teachers followed up the learning from the CPD and completed cycles in which, at the beginning, the modules were planned and, as a draft, written (either alone or in groups), then discussed at the next meeting. When the teachers thought their modules were in an appropriate format and level of completeness, each teacher prepared to test their own specific module in the classroom. Based on student feedback and self-reflection, each teacher evaluated the module and then with support from the other teachers, as appropriate, modified their modules. In so doing, all teachers followed similar stages of an action research cycle. This type of action research has also been practiced and documented by Vaino et al. (2013) and identified with good results within a short professional development programme. Vaino (2013) referred to this as collaborative action research and showed that close cooperation, through the format of collaborative action research, especially group reflections, perceived collegial support, and dissemination of modules to the wider audience turned out to be an effective approach for the changing of teacher beliefs and encouraging teachers to implement new instructional practices.

Based on the results of the current study, it is argued that teachers who achieved a higher level of self-efficacy at the end of CPD programme (table 1) were in a position to initiate steps towards the planning and creating of teaching-learning modules, reflecting the ideas put forward in the CPD. They were able to collaboratively discuss the way forward with colleagues and to collectively participate in aligning the modules to the proposed model, prepare a student feedback questionnaire and try out the modules in the classroom situation.

One year after the initial participatory action research, the researcher determined it was appropriate to determine the level of ownership of the philosophical ideas and approaches towards the 3-stage 'education through science' teaching held by the teachers. The goal was to identify attributes that meaningfully contribute to teacher ownership and how the teacher ownership could be categorized, based on characteristics associated with conceptualising the new teaching approach (Research question 4).

In this thesis, teacher ownership is seen as being determined and described at three different levels. These are determined by reflecting on dimensions of different variation expressed, when the teachers are involved in an interview and exhibiting their portfolios covering their students' work through developing and using modules in the classroom. The variations found to play an important role in identifying the type of teacher ownership are found to be (table 13):

(a) Reflection type.
(b) Motivation.
(c) Inquiry activities.
(d) Decision-making.
(e) Purpose of teaching.
(f) Gains for the CPD.
(g) Constraints face in teaching.

Based on the group responses to these 7 variations, in which the more dominant variation is the reflection type, the 3 categories of ownership can be described as emotional, experiential and paradigmatic. Emotional ownership is used to describe a sense of ownership which utilised operational elements of the 3-stage model, but which was not interpreted as per the intended philosophy and approach. This sense of ownership is very subject oriented. Experiential ownership is used as further step towards teacher ownership, describing teachers who possessed the ability to use the intended approach as per a socio-scientific introduction to scientific learning and applying the science in a societal situation, but face difficulty in overcoming constraints. Paradigmatic ownership is used to describe the highest level of ownership of the 'EtS' philosophy and in operationalizing a context-based approach as per the 3-stage teaching model. It indicates that the teacher has undergone a paradigmatic shift to permanently accept the intended philosophy and approach (Rannikmäe, 2001) and is capable of meaningfully conveying this to others (Paper V).

The three levels of teacher ownership associated with acceptance, belief and accurately portraying the 3-stage approach and underlying philosophy to others, can be meaningfully described. Furthermore, a sense of ownership has no real meaning beyond that associated with self-efficacy in being able to operate based on the outcomes of the CPD. Furthermore, these 3 levels of ownership are indicated to be unique not in line with findings by other researchers. Some similarities can be found with a study by Fullan (1991). Fullan offers, as outcomes, three key dimensions for changes in practice:

a. The possible alteration of beliefs.
b. Possible use of new teaching approaches.
c. Possible use of new or revised materials.

This study recognises the value of Fullan's findings as a context for describing possible outcomes of an intervention. However, this research has sought to go further and show how those aspects appear among the descriptors of different teacher ownership categories.

The earlier study by Rannikmäe (2001) also identifies three categories of teacher ownership, in this case towards scientific and technological literacy (STL) teaching. These are seen as – subject learning activity based; sequenced activity based, and social issue based. The social issue based category can be identified with the dimension geared to decision making, positively supported by the paradigmatic level of ownership The full ownership identified by Rannikmäe can be equated with the paradigmatic teacher ownership identified in this research. This research is more strongly detected through teacher reflections on considering future actions rather than on relating to issues arising from the society at the local, national and global level.

6. CONCLUSIONS

In undertaking this study, four research questions were addressed:

1. What do teachers, who had previously been introduced to 'education through science' philosophy-based teaching modules, recommend for inclusion and delivery within a planned, continuous professional development (CPD) programme to raise its effectiveness for other science teachers?

Suggested recommendations by teachers previously introduced to teaching modules following a 3-stage approach, to take into account when planning a future longitudinal, learner-centred, interdisciplinary CPD programme, were:

- A clear explanation of the philosophical rationale.
- Use of exemplar materials that are classroom ready.
- Additional guidance on inquiry-based learning and assessment.
- Promotion of the teaching of argumentation and reasoning skills.

Teachers saw the value in the continuing use of modules and longitudinal, learner centred, interdisciplinary courses, which include intervention by the teacher in the classroom and which have a positive lasting impact on a teacher's opinion.

2. What are science teachers' professional needs to raise their self-efficacy to promote motivational, context-based student science learning associated with a competence-based curriculum?

Based on outcomes from self-identified teacher needs, geared on 'education through science' attributes, it can be concluded that science teachers' professional needs to gain self-efficacy to undertake teaching, based on a 3-stage approach, were particularly prevalent in five sub-scales:

- Inquiry-based learning.
- Assessment strategies.
- Student motivation strategies.
- Teacher self-reflection.
- Knowledge of relevant theories of education.

Findings from teacher pre-intervention interviews supported the self-identified teacher needs. An emphasis in the CPD programme was clearly needed related to the 'education through science' philosophy and how this can be operationalised in teaching-learning modules.

3. What components of a CPD programme are deemed effective in raising science teacher's self-efficacy, identified by teacher reflections on trying out the proposed teaching approach?

A constructivist, socio-cultural professional model, taking into account Bandura's self-efficacy determinants, could be used to develop a CPD programme, having a positive impact on teacher's self-efficacy by meeting teachers' needs.

Within such a CPD programme, the components found to be of value in promoted teacher self-efficacy were:

- Interdisciplinary lecture presentations within the 'teacher as learner' component.
- CPD effectiveness, felt in all sub-scale areas, but especially in the 'teacher as teacher' aspects on inquiry-based learning, theories of education and assessment.
- For 'teacher as a reflective practitioner,' the teachers pointed to the raising of self-efficacy through working through modules and the reflective sessions as areas of strong support within the CPD.
- Going through a module collectively to develop better understanding and explore possibilities for sharing best practice leading to a change of teacher beliefs.

4. What are the main characteristics of teacher ownership, which enables the determination of levels of teacher ownership in conceptualizing and operationalising a motivational, context-based teaching approach?
Seven characteristics pertaining to teacher ownership in operationalising a 3-stage model approach, built on an 'education through science' philosophy were identified and labelled as: reflection type, student motivation, inquiry activates, decision-making, purpose of teaching, identified by teacher`s constraints and gains from in-service programme.

- The main characteristic describing permanent change (one year later after the intervention) is found to be the type of reflection. A teacher, who has reached to the level of permanent ownership, is orientated in their reflection to consider future developments. Reflection is an important factor in influencing teacher's practices and beliefs.
- Based on the seven categories, three ownership levels can be distinguished and labelled as: emotional, experiential and paradigmatic.
- The most complicated change in teacher beliefs is the usefulness of involving socio-science issues for student motivational purposes and undertaking socio-scientific decision-making.
- Developing teacher self-efficacy is an initial step towards promoting ownership and decreasing external constraints (e.g. time, lack of tools, curriculum demands) to use a 3-stage, 'education through science' (EtS) teaching-learning approach.
- Teachers more willing to adapt to multi-subject teaching also pay more attention to interdisciplinary knowledge and their approach to teaching.
- Teachers, exhibiting ownership levels at the experiential and emotional levels, tend to indicate the need for further consultation and support.

7. IMPLICATIONS AND RECOMMENDATIONS

Although limited in its scope, the current study provides recommendations and implications with respect to future considerations associated with the professional development of science teachers.

1. Implications and recommendations for science.
This study expands understanding of 'teacher ownership' in the context of science education and puts forward a theoretically justified CPD model, based on identifying teachers needs to operationalize a 3-stage model approach, built on an 'education through science' philosophy.

'Teacher needs' is a theoretical construct that fills the gaps between existing theories and practice. It targets components of teaching and learning that need in particular educational environments to the focus on enhancing multidimensional science literacy in all its complexity.

Future studies need to pay more attention to the distinction between teacher self-efficacy and ownership; provide further insights into how self-efficacy can form a base to lead the teacher to permanent ownership. Dissemination of the results of this study and the initiation of new research in other cultures of the world, can give sustainability to the concept of ownership and a CPD model, based on identified teacher needs.

2. Implications and recommendations for practice.
Future teacher in-service education programmes need to consider seven strategies to support effectively professional development of experienced teachers leading to the sustained change in their teaching and to aspire to the ownership and paradigm shifts towards the 'education through science' philosophy. These are:

- Providing teachers with in-service training that takes into account their prior experience and needs. It is desirable to measure training needs through two components: self-confidence and perceived training needs. The involvement of teachers in the planning of the training programme ensures that the training meets the needs of teachers and creates a situation for teachers to learn and change their teaching style.
- Supporting teachers' development in three areas 'teacher as learner', 'teacher as teacher' and 'teacher as reflective practitioner' to ensure the competence and confidence to use new teaching/learning materials (in this study a 3-stage 'education through science' model).
- Providing teachers with innovative learning materials with opportunities to practice their use in the classroom over a prolonged period of time and experience mastery.
- Providing teachers with training materials and supporting them to modify these according to the needs and interests of their students, increasing the self-efficacy of teachers through the growth of competence and self-confidence.

- Providing teachers with frequent possibilities of individual and group reflections on their on-going practices as useful sources for vicarious learning, social persuasion and positive emotions.
- Organising the design of innovative learning materials by teachers using action research methods to support steps to attaining ownership.
- Providing teachers with opportunities to introduce their innovative practices and the results of their action research to a 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.

3. Implications and recommendations for economy and policy.
This study seeks to build a platform for science teachers to motivate students in learning science and therefore encourage more students to take up science-related careers and educating all students according to the needs of society. This study seeks to influence educational policy and curriculum development by drawing attention to the need for changes in science education and builds an appropriate platform for a successful paradigm shift towards an ‘education through science’ philosophy. The ‘education through science’ philosophy is thus shown to be of interest to all curriculum developers and teacher educators.

8. LIMITATIONS

The research had limitations because of the comparatively small sample size of voluntary teachers involved in the CPD, who could not be taken as representative of Estonian teachers as a whole. The teachers were motivated to join the programme, use modules in their classroom and were willing to reorganize their teaching programme to accommodate this.

APPENDICES

Appendix 1. Overview of the 3-stage Modules Used in This Study

Title of 3-stage module	1-stage	2-stage	3-stage	Content
I love sweets but I am prohibited to eat/ Siiri Sugarlump – loves candies. (PARSEL module modified by A. Valdmann)	Siiri does not want to eat a school lunch and instead buys snacks. What happens after years? What is a healthy diet?	Group work on a freely chosen topic based on a scenario (information retrieval, analysis, and presentation) Guided inquiry (hands-on): Food and Nutrition – Examination of food packaging, determination of starch or lipids in food.	Either analysing your weekly menu using the Nutridata programme, or creating advertisements for a healthy diet.	Healthy diet. Food and nutrition. Gastrointestinal tract and digestion. The construction, properties and importance of carbohydrates and lipids.
Fitness club versus running. Trained people are smart, strong and beautiful. (Author A. Valdmann)	The boys dispute with each other whether it's better to go to the gym or run. Which exercise to choose? How does exercise influence human heart activity and respiration?	Group work for information search and presentations: Heart, lung and muscle anatomy and function. Guided inquiry (hands-on): determination of heart rate, blood pressure and respiration.	Essay "Do you want to change your movement habits?"	Healthy lifestyles. Cardiovascular anatomy and function. The respiratory tract. Muscles and muscular work. Exercise effects on the human body. Aerobic and anaerobic work.
Keep milk cold. (PARSEL module modified by A. Valdmann)	Students prepare a list of foodstuffs for going to the cottage. Some children think that it is definitely necessary to bring milk, but there is no fridge in the summerhouse. What dairy products can you take with you? Is dairy consumption important for health?	Group work for information search and presentations: Milk components and their importance for health – Comparison of the composition of dairy product packaging, milk allergy and lactose intolerance, the role of microorganisms in the acidification of milk. Guided inquiry (hands-on): acidification and preservation of milk. Comparison of different dairy compositions and taste properties.	Discussion and solution to the problems in the scenario. (Why can some people not drink milk and what should they do? How to keep milk fresh?)	Healthy diet. Osteoporosis. Importance of microorganisms. Lactic acid fermentation. Proteins.

Title of 3-stage module	1-stage	2-stage	3-stage	Content
Dietary Supplements: for or against. (Author A. Valdmann)	The boys will argue if and which protein supplements should be used in sports. Are protein preparations necessary and safe? Where is it safe to buy supplements from?	Group work: The structure, properties and role of proteins in the human body. Health risks associated with over and under consumption of proteins. Comparison and assessment of various compositions and advertisements of protein drinks. Analysis of your weekly menu. Guided inquiry (hands-on): Determination of proteins.	Debate Dietary Supplements: for or against.	Healthy lifestyle. The structure, properties and role of proteins in the human body.
Lara (16) is pregnant. PARSEL.	A presentation in which a 16-year-old girl tells her friends and parents that she is pregnant. What should Lara do?	Group work on specific topics. Collection of arguments for and against abortion.	Write a letter to Lara.	Pregnancy. Foetal development. Abortion. Pregnancy prevention and counselling.
Estonian Nokia: insulin-producing cow? (Author A. Valdmann)	The EU Commission received a request for funding a research project for the creation of genetically modified organisms. What are the risks associated with the creation and spread of genetically modified organisms?	Collection of information on the cloning of insulin producing cows created at the University of Life Sciences. Role-play “The work of the project application evaluation committee”: Each member of the group, according to his role, will seek information about the creation and risks of genetically modified organisms. The group must decide whether to fund a research project.	Role-playing summaries and presentation of your decision and justification for the whole class.	Genetically modified organisms, possibilities for their creation and cloning. The risks associated with the spread of GMOs.
What kind of soil do plants need to grow? (Author A. Valdmann)	Two farmers, who have the same amount of land and grow the same crops, receive a completely different harvest quantity. Why are they getting different results?	Guided inquiry (hands-on): Comparison of soil samples, pH and absorption. Change the soil pH. Effect of soil pH on crop production.	Discussion of soil fertility and factors affecting plant growth. Decision-making how to increase productivity.	Soil as an ecological factor. Crop rotation. Organic farming.

Title of 3-stage module	1-stage	2-stage	3-stage	Content
Smells-only cosmetics? (Author K.Vaino)	Slideshow. Young people who have just returned from Egypt are being detained at an airport because the drug dog has discovered something suspicious in their luggage. Why might the drug dog have been standing behind this luggage?	Video about the training of drug dogs. Group work: fruit distillation or perception of smell. Guided inquiry (hands-on): separation of essential oils from plant material.	Decision-making based scenario.	Essential oils, distillation.
Toxic substances: what is the price of luxury? (Author K. Kask)	Slideshow about home chemistry (cleaning products).	Group work: Toothpaste composition study. Guided inquiry (hands-on): Preparation of toothpaste. Comparison of the washing properties of homemade and purchased toothpastes.	Essay "Are we paying the right price for luxury?"	Safety requirements for the use of household chemicals. Chemistry and living environment.
Oil-King of the world or its Achilles' heel. (Author K. Kask)	A section on an article describing the consequences of the oil spill in the Gulf of Mexico.	Open inquiry. Elimination of oil pollution and the cleaning of birds from oil.	Role-play "Oil is either the king of the world or its Achilles' heel".	Impact of human activity on ecosystems, possibilities of solving environmental problems. Solutions and sprays, hydrophilic and hydrophobic substances, calorific value, hydrocarbon occurrence in nature, possibilities for their use in practice.
Coca-Cola: Myths and Reality. (Author K. Kask)	A lot of attention has been paid to the health risks of drinking Coca Cola in the media. The scenario calls for the search of evidence based on experiments and critical analysis of information.	Group work: Comparison of composition of soft drinks. Guided practical work Determine the phosphoric acid content in Coca-Cola.	Debate over and against Coca-Cola. Broken Myths.	Healthy diet. Acids, acid properties, neutralization reaction, pH, molar concentration, conversion of units.

Title of 3-stage module	1-stage	2-stage	3-stage	Content
Which soap is best? (Author K. Vaino)	There are many different types of soap in the shop. Students are invited to carry out a design project to decide which soap is best.	Group work. Comparison of different soap compositions. Guided inquiry (hands-on): Soap testing. Comparison of the cleaning effectiveness of the soaps.	Choosing the best soap and reasoning.	Chemical background for soap making. Different types of soap and skin properties. The importance of hygiene.
How Happy are You and Your Family with the Electricity Bill? (PARSEL)	Today, thanks to technological innovations, more and more equipment need electricity in their operation. Due to high electricity consumption, the electricity bill has become an important monthly expense for families. Is your family satisfied with the electricity bill?	Group work: Comparison of the electricity bills of different families. Preparation and implementation of a questionnaire on electricity consumption. Guided inquiry (hands-on): Measuring electricity consumption in your home.	Discussions about the use of electrical equipment and the possibility of reducing electricity bills.	Electricity, electricity generation in Estonia, Green energy. Measurement of electrical consumption. Environmentally friendly consumption.
Should we do more to save cultural monuments from corrosion? (PARSEL)	Several cultural monuments show signs of damage. Why? Is there anything we can do to save these sculptures?	Guided inquiry (hands-on): Preventing corrosion of copper and iron. Derivation of an electrochemical series (Volta pillar).	The debate is whether we should do something to save monuments.	Corrosion, reactivity line. Acid rains. Reducing air pollution.
How to Best Maintain a Metal Bridge? (PARSEL)	The village's only bridge is broken and needs renovation.	Open inquiry: How to protect metal from corrosion? Which option is the most economically profitable?	Community meeting: How to renovate a bridge?	Corrosion, reactivity line. Acid rains. Reducing air pollution.
A big problem for Magalhães: Food preservation. (PARSEL)	In the sixteenth century, Magalhães is set to take its ship to Seville to find sea routes to the Curonian Spit island of Indonesia. After three years, only 18 out of 200 men return, the others having died from hunger due to food spoilage.	Group work: Preparing a trip. What kind of food and how much to take with us? How to store this food? Open inquiry. Fish and meat preservation.	Written summary of food storage options.	Food preservation. Micro and macronutrients. Their importance in human metabolism. Health problems due to vitamin deficiency. The energy value of food.

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SUMMARY IN ESTONIA

Loodusteaduste õpetajate enesetõhususe kategooriate ja omanikutunde tasemete määramine lähtudes õpetajate koolitusvajadustest

Ühiskonna tulevikusuundumused eeldavad kõigi selle liikmete senisest paremat arusaamist loodusteadustest ja tehnoloogiast tagamaks nende aktiivset ja vastutustundlikku osalemist sotsiaalsetes otsustusprotsessides ja teadmistepõhises innovatsioonis (EC, 2015). Nimetatud eesmärke peetakse ühtlasi loodusteadusliku kirjaoskuse olulisteks komponentideks (Roberts & Bybee, 2014). Selle väljakutse ühe võimaliku vastusena nähakse sotsiaalsete ja tehnoloogiliste aspektide ning uurimusliku lähenemise senisest tõhusamat rakendamist loodusteaduste õpetamisel-õppimisel (OECD, 2016). Relevantsete probleemide käsitlemise kaudu tuleks kujundada õpilaste arusaamist probleemi loodusteaduslikust sisust ning oskust kasutada loodusteaduslikku uurimismeetodit ja põhjendamisoskust (Sadler, Foulk & Friedrichen, 2017). Samas tuleks õppeprotsessi käigus neid oskusi ka hinnata (Romine, Sadler, & Kinslow, 2017).

Antud eesmärgi saavutamiseks tuleks teha olulisi muudatusi üldhariduskooli loodusteaduste õpetamisel ning loodusteaduste õpetajate ettevalmistamisel (Wallace & Loughram, 2011). 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 (Desimone, 2009; Kennedy, 2014).

Uurimused on tõestanud, et õpilaste loodusteaduslikku ja tehnoloogiaalast kirjaoskust saab tõhusalt arendada „haridus loodusteaduse kaudu" filosoofial (Holbrook & Rannikmäe, 2007) põhineva lähenemisviisi abil. Antud filosoofiale tuginedes on Holbrook ja Rannikmäe (2010) loonud kolmeastmelise õpetamise mudeli, mille alusel on EU FP 7 PROFILES (http://www.profiles-project.eu) raames välja töötatud rida mooduleid. Samas puudub teaduslikult põhjendatud õpetajate täiendkoolitusprogrammi mudel, mis toetaks õpetajate enesetõhusust antud lähenemisviisi rakendamisel ning selle lähenemisviisi omaksvõtmist (omanikutunde kujunemine *ownership)*. Eelnevast tulenevalt püstitati käesoleva doktoritöö eesmärkideks:

- Töötada välja teaduslikult põhjendatud loodusainete õpetajate täiendkoolitusprogramm, mis põhineb eelnevalt kindlaks määratud õpetajate koolitusvajadustele, et rakendada õpetamisel „haridus loodusteaduste kaudu" filosoofia põhimõtteid.
- Hinnata väljatöötatud täiendkoolitusprogrammi efektiivsust.
- Toetada tegevusuuringu (*participatory action reseach*) kaudu õpetaja õpetajate arvates nende jaoks efektiivsemaks filosoofia ja lähenemisviisi suhtes. Defineerida ja määrata õpetaja omanikutunde tasemed lähtudes õpetajate valimisolekust edastada nii filosoofiat kui ka lähenemisviisi kolleegidele.

Vastavalt eesmärkidele püstitati neli uurimisküsimust:

1) Milliseid soovitusi annavad õpetajad, kes on eelnevalt osalenud täiendkoolitusel ning praktikas kasutanud „haridus loodusteaduste kaudu" filosoofial põhinevaid õppematerjale, et muuta uus täiendkoolitus õpetajate arvates nende jaoks efektiivsemaks? (Artikkel 1)
2) Millised on loodusainete õpetajate koolitusvajadused, et suurendada nende enesetõhusust õpetada loodusaineid motiveerivalt ja kontekstipõhiselt toetades õpilaste riiklikus õppekavas märgitud kompetentsuste arengut? (Artikkel 2)
3) Millised väljatöötatud koolitusprogrammi komponendid toetavad „haridus loodusteaduste kaudu" kolmeastmelise mudeli tähendusrikast kasutamist õpetamispraktikas? (Artiklid 3 ja 4)
4) Millised on õpetajate omanikutunde karakteristikud, mis võimaldavad kindlaks määrata õpetaja omanikutunde tasemeid motiveeriva, kontekstipõhise õpetamisviisi kontseptualiseerimisel ja rakendamisel, mis põhineb „haridus loodusteaduste kaudu" filosoofial? (Artikkel 5)

Kestvusuuringus (2010–2015) kasutati kolme valimit. Esimese valimi moodustasid viis loodusainete õpetajat, kes olid kõik eelnevalt osalenud PARSEL projektis ja läbinud lühiajalise koolituse ning kasutanud oma õppetöös „haridus loodusteaduste kaudu" filosoofial põhinevaid mooduleid. Teine oli mugavusvalim, mille moodustas 27 vabatahtlikku loodusainete õpetajat, kes soovisid osaleda koolitusel ja andsid nõusoleku osaleda antud uuringus. Kolmanda valimi moodustasid 10 õpetajat (eelneva 27 õpetaja hulgast), kes soovisid jätkata tegevusuuringuga ning andsid nõusoleku osaleda jätkuuuringus.

Antud uuring koosnes 4 etapist:

1) Täiendkoolitusprogrammi planeerimine, milles osalesid valimi 1 ja 2 õpetajad (2010–2011).
2) Täiendkoolitusprogrammi läbiviimine ja efektiivsuse hindamine, milles osalesid valimi 2 õpetajad (2011–2012).
3) Tegevusuuring, milles osalesid valimi 3 õpetajad (2012–2014).
4) Õpetajate „haridus loodusteaduste kaudu" omanikutunde karakteristikute ja tasemete määramine, milles osalesid valimi 3 õpetajad (2015).

Esimeses etapis koguti andmeid poolstruktureeritud intervjuu abil viielt õpetajalt, kellel oli eelnev PARSEL projekti raames toimunud õpetajate täiendkoolituse kogemus. Intervjuude läbiviimise eesmärgiks oli teada saada, kuidas muuta täiendkoolitus efektiivsemaks ja milliseid raskusi tekkis õpetajatel „haridus loodusteaduste kaudu" filosoofial põhinevate õppematerjalide rakendamisel. Õpetajate koolitusvajaduste kindlakstegemiseks arendati välja rahvusvaheliselt valideeritud (PROFILES partnerite poolt) Õpetajate Koolitusvajaduste Küsimustik (*Teacher Needs Questionnaire TNQ*). Küsimustiku teoreetiline raamistik põhineb „haridus loodusteaduste kaudu" filosoofial ning Bandura (1977) enesetõhususe kontseptsioonil. 27 loodusaineteõpetaja Õpetajate Koolitusvajaduste Küsimustiku (TNQ) tulemused olid koolituse sisu planeerimise aluseks.

Koolituse disaini teoreetiliseks aluseks võeti konstruktivistlik sotsiaal-kultuuriline koolitusmudel *(Constructivist Sociocultural Professional Model – CSPM)* (Howe & Stubbs, 1997; Brand & Moore, 2010), mis rõhutab eelneva kogemuse ja teadmise tähtsust uute teadmiste omandamisel ning toetava kultuurilise ja sotsiaalse keskkonna loomise vajalikkust, samuti õppija kaasamist koolituse planeerimisse ning reflektsiooni. Koolituse planeerimisel arvestati Bandura enesetõhusust kujundavate teguritega, milleks on meisterlikkuse kogemine, sotsiaalne mudeldamine, sotsiaalne veenmine ja emotsionaalsed ning füüsilised seisundid (Bandura, 1977). Lisaks lasti õpetajatel kogeda erinevaid rolle: „õpetaja kui õppija" , „õpetaja kui õpetaja" ning „õpetaja kui reflekteeriv praktik" (Hofstein & Mamlok-Naaman, 2014).

Uurinu teises etapis, täiendkoolitusprogrammis, osales 27 loodusaineteõpetajat. Täiendkoolitusprogramm kestis ühe õppeaasta, mille olulisteks osadeks olid õppemoodulite kasutamine praktikas, kogemuste jagamine ning reflektsioon. Koolituse efektiivsuse hindamiseks koguti andmeid Õpetajate Koolitusvajaduste Küsimustiku (TNQ), õpetajate pool-struktureeritud intervjuude ning kokkusaamiste heliülesvõtete abil.

Uuringu kolmandas etapis osales 10 õpetajat. Tegevusuuringu käigus (Eilks & Ralle, 2002) õpetajad lõid oma õpilaste ja õppekava jaoks relevantse „haridus loodusteaduste kaudu" filosoofial põhineva õppemooduli, kasutasid seda õppetöös ning hindasid mooduli abil saavutatud õpitulemusi. Autori ülesandeks oli uurida õpetajate omanikutunde kujunemist soodustavaid ja takistavaid tegureid ning toetada õpetajaid kolmeastmeliste moodulite loomisel.

Aasta pärast tegevusuuringu läbiviimist (uuringu neljandas etapis) kaardistati, kuidas õpetajad kogevad, kontseptualiseerivad, tajuvad ja mõistavad „haridus loodusteaduste kaudu" filosoofiat ning sellel põhinevat õpetamisviisi. Selleks kasutati fenomenograafilist meetodit (Marton, 1986, Akerlind, 2012) ning lõpp-tulemusena töötati välja õpetajate omanikutunnet kirjeldavad tasemed.

Kestvusuuringuga saadud järeldused püstitatud uurimisküsimustele on järgmised:

Viie õpetaja arvates, kellel oli eelnev kogemus osalemisel PARSEL'i projekti koolitusel ja moodulite kasutamisel, muudab uue täiendkoolitusprogrammi efektiivsemaks kui:

- Koolitus on pikemaajaline, õppijakeskne ja arvestab õpetajate eelneva kogemusega.
- Antakse põhjalik ülevaade „haridus loodusteaduste kaudu" filosoofiast ja selgitakse põhjalikumalt, kuidas see seostub kolmeastmelise mudeliga.
- Moodulid on koheselt rakendatavad praktikas ning peale moodulite kasutamist on võimalus ühiseks aruteluks.
- Pööratakse tähelepanu uurimusliku õppe läbiviimisele, õpilaste argumenteerimisoskuse arendamisele.
- Selgitatakse moodulite hindamisjuhendeid (kujundava hindamise võtmes).

- Kolmeastmelise mudeli paremaks mõistmiseks võiks koolitusel mooduli läbi mängida, kasutades selleks rollimängu.

Õpetajate Koolitusvajaduse Küsimustiku tulemuste põhjal vajasid õpetajad kõige enam koolitust järgmistes valdkondades: uurimuslik õpe, hindamise strateegiad, õpilaste motiveerimise strateegiad, haridusteooriad, eneseanalüüsi tehnikad.

Kolmeastmelise mudeli tähendusrikast kasutamist õpetamispraktikas soodustasid järgmised koolitusprogrammi komponendid:
- Kolmeastmelise mooduli läbimängimine (õpetaja kui õpetaja).
- Kogemuste jagamine pärast moodulite kasutamist (õpetaja kui reflekteeriv praktik).
- Interdistsiplinaarsed loengud, mis toetasid moodulite ainealast sisu (õpetaja kui õppija).

Täiendkoolituse efektiivsuse määramiseks kasutati eel- ja järelküsimustikku (pre- and post-TNQ). Täiendkoolituse efektiivsuse näitajatena identifitseeriti õpetajate enesekindluse kasv ja koolitusvajaduste vähenemine ning õpetajate liikumine koolituse käigus madalamast enesetõhususe klastrist kõrgemasse.

Fenomenograafilise analüüsi tulemusena saadi tulemuskategooriateks: reflektsiooni tüüp, õpilaste motiveerimine, uurimuslik lähenemine õpetamisele, otsuse tegemine, õpetamise eesmärgid, koolitusel saadud kasu, takistused õpetamisel. Tulemuskategooriate süsteemi alusel jaotati omanikutunne „haridus loodusteaduste kaudu" kolmele tasemele paradigmaatiline, eksperimentaalne ja emotsionaalne. Tasemed *(levels)* on hierarhilise struktuuriga ja eristavaks tunnuseks on õpetajate reflektsiooni tüüp. Paradigmaatilisel tasemel olevad õpetajad, keskendusid probleemide lahendamisele tulevikus, pidades oluliseks õpilaste motiveerimist läbi sotsiaal-loodusteadusliku konteksti, kasutasid avatud uurimuslikku õpet ning otsuse tegemisel pidasid oluliseks nii sotsiaalsete, majanduslike, eetiliste, kultuuriliste kui teaduslike argumentide kasutamist. Õpetajad on omaks võtnud „haridus loodusteaduste kaudu" filosoofia ning õpetamisviisi, järgivad seda oma igapäevatöös ning jagavad oma kogemust aktiivselt teiste loodusainete õpetajatega.

Eksperimentaalsel tasemel olevad õpetajad pidasid oluliseks uute õpetamismeetodite katsetamist ning märkasid õpetamisel tekkinud probleem, kuid ei pööranud tähelepanu lahendustele. Nad kasutasid aktiivselt valmis mooduleid ja modifitseerisid neid vastavalt oma õpilaste vajadustele, kuid ei järginud kolmeastmelise mudeli kõiki etappe moodulite loomisel.

Emotsionaalsel tasemel olevad õpetajad rõhutasid oma positiivseid emotsioone kui nad kasutasid kolmeastmelisi mooduleid õpetamisel. Samas kasutasid nad valmismooduleid fragmentaalselt, pöörates enam tähelepanu teaduslikule probleemile ja selle lahendamisele, jättes kõrvale sotsiaalsed, kultuurilised, eetilised ja majanduslikud aspektid.

Eelpool öeldu põhjal võib väita, et kõige keerukam on loodusainete õpetajate jaoks sotsiaalse konteksti toomine tundi ning samuti sotsiaalsete aspektide arvestamine otsuse tegemisel.

Käesoleva doktoritöö panus teadusesse seisneb konstruktivistliku sotsiaal-kultuurilise koolitusmudeli (Howe & Stubbs, 1997; Brand & Moore, 2010) täiendamises ning loodusainete õpetajate koolitusvajadusi mõõtva uurimis-instrumendi väljatöötamises. Seda uudset teaduslikult põhjendatud lähenemist, kus koolitusvajadusi mõõdetakse läbi kahe aspekti (enesekindlus ja pädevus-tunne), on võimalik rakendada ka teiste õppeainete õpetajate täiendkoolitus-vajaduste kindlaksmääramiseks. Lisaks võimaldab instrument hinnata koolituse enda efektiivsust.

Käesolevas doktoritöös väljatöötatud „haridus loodusteaduste kaudu" filo-soofia ja õpetamisviisi omaksvõtu tasemed ja nende kirjeldused on unikaalsed.

Fenomenograafilise lähenemise kasutamine koolitusprotsessi efektiivsuse ja selle pikaajalise mõju hindamisel on laiendatav täiskasvanukoolituse kõigis valdkondades.

Antud töös väljatöötatud õpetajate täienduskoolitusmudel ning töö käigus loodud õppematerjalid omavad suurt praktilist väärtust loodusainete õpetajate jaoks ning on abiks loodusteadusliku hariduse eesmärkide saavutamisel Eesti koolides.

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ORIGINAL PUBLICATIONS

CURRICULUM VITAE

Name: Ana Valdmann
Date of birth: 25.03.1964
Citizenship: Estonian
Work address: Centre for Science Education
University of Tartu,
Vanemuise 46, Tartu, 51014, Estonia
Phone: + 372 7375083
E-mail: ana.valdmann@ut.ee

Education:

2010…	University of Tartu, Faculty of Science and Technology, PhD studies in science education
2001–2005	University of Tartu, Faculty of Education, School Management, master's studies
1993–1997	University of Tartu, Faculty of Philosophy, Educational science, bachelor's studies
1982–1987	University of Tartu, Faculty of Biology and Geography, Biology, bachelor's studies
1979–1982	Pärnu 6. Secondary School
1971–1979	Pärnu 4. Secondary School

Professional employment:

2016…	Tartu Veeriku School, teacher
2017	University of Tartu, Faculty of Science and Technology, Junior Research Fellow of Science Education
2014–2015	University of Tartu, Faculty of Science and Technology, Junior Research Fellow of Science Education
2014–2015	Tartu Hansa School, teacher
2011–2014	University of Tartu, Faculty of Science and Technology, Specialist of Science Education
1996–1998	ÖselFoods, microbiologist
1987–2014	Tartu Secondary School of Business, teacher

Field of research:

Development of students' scientific and technological literacy, the design and evaluation of structures supporting science teachers' professional development.

Publications:

Valdmann, A., Holbrook, J., & Rannikmäe, M. (2017). Determining the effectiveness of a design-based, continuous professional development programme for science teachers. *Journal of Baltic Science Education, 4(16),* 576−591.

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ELULOOKIRJELDUS

Nimi:	Ana Valdmann
Sünniaeg:	25.03.1964
Kodakondsus:	Eesti
Aadress:	Loodusteadusliku hariduse keskus Tartu Ülikool Vanemuise 46, Tartu, 51014, Eesti
Telefon:	+ 372 737 5083
E-post:	ana.valdmann@ut.ee

Haridustee:

2010…	Tartu Ülikool, loodus ja täppisteaduste valdkond, loodusteaduslik haridus, doktoriõpe
2001–2005	Tartu Ülikool, haridusteaduskond, koolikorraldus, magistriõpe
1993–1997	Tartu Ülikool, filosoofiateaduskond, kasvatusteadused, bakalauruseõpe
1982–1987	Tartu Ülikool, bioloogia-geograafiateaduskond, bioloogia, bakalauruseõpe

Teenistuskäik:

2016…	Tartu Veeriku Kool, õpetaja
2017 …	Tartu Ülikool, loodus- ja täppisteadustevaldkond, loodusteadusliku hariduse keskus, nooremteadur
2014–2015	Tartu Ülikool, loodus- ja tehnoloogia teaduskond, loodusteadusliku hariduse keskus, nooremteadur
2014–2015	Tartu Hansa Kool, õpetaja- metoodik
2011–2014	Tartu Ülikool, loodus- ja tehnoloogia teaduskond, loodusteadusliku hariduse keskus, spetsialist
1996–1998	ÖselFoods, mikrobioloog
1987–2014	Tartu Kommetsgümnaasium, õpetaja

Teadustegevus:
Loodusteaduste õpetajate professionaalse arengu toetamine eesmärgiga tõsta õpilaste loodusteaduslikku ja tehnoloogiaalast kirjaoskust ning motivatsiooni.

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