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DETERMINING THE EFFECTIVENESS OF A CPD PROGRAMME FOR ENHANCING SCIENCE TEACHERS' SELF-EFFICACY TOWARDS MOTIVATIONAL CONTEXT-BASED TEACHING

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Abstract. *The aim of this research is to determine the effectiveness of an enacted professional development (CPD) programme to promote teacher's self-efficacy with respect to implementing motivational, context-based science teaching, following an education through science (EtS), three-stage model approach. The CPD is designed, based on a constructivist, socio-cultural professional development model (CSPM) to meet professional needs of each teacher within a predetermined teaching-learning approach and enacted through suitable instructional methods linked to teacher as learner, teacher as teacher and teacher as reflective practitioner. The effectiveness of the CPD is identified by means of a carefully constructed and validated Teacher Needs Questionnaire (TNQ), plus follow-up teacher interviews. Findings suggest the outcomes of the CPD, both from pre-post use of the TNQ and the undertaking of interventions, using teaching-learning modules based on the CPD, are effective in raising teacher's self-efficacy with respect to new interdisciplinary content knowledge, teaching approaches and classroom implementation, seen as being in line with curriculum expectations.*

Key words: *constructivist socio-cultural professional development model (CSPM), self-efficacy, Teacher Needs Questionnaire (TNQ), 3-stage education through science (EtS) model.*

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Introduction

Many countries are seeking to introduce paradigm shifts in science teaching to address concerns related to a lack of relevance in science teaching together with science lessons being seen as boring, too abstract and also perceived by students as difficult (EC, 2007). Such paradigm shifts are also related to rethinking the purpose of science education, away from being a base for further education and towards a wider educational vision (Symington & Tytler, 2004; Fensham, 2008; Holbrook, 2008; Fernandez, Holbrook, Naaman-Mamlok & Coll, 2013). In Estonia, a new competence-based national curriculum, accompanying on-going educational reforms, is intended to lead to significant changes in its school system and bridge the gap between theoretical knowledge and the needs of the modern society with students learning to:

> "*Use scientific knowledge to solve problems and to make reasoned decisions that impinge on environmental issues, as well as issues associated with life in the home, at the place of work, or in the community; value science as a part of culture, essential for understanding a responsible and sustainable way of life and determining sustainable uses for natural resources*" (Estonian Government, 2011).

Teachers are confronted with the fact that a new competence based curriculum requires a different approach to teaching, yet at the same time, innovative, contemporary and effective teaching materials are seldom available, coupled with the fact that facilities to provide authentic training courses or long term professional development programmes for science teachers are rare.

The Estonian curriculum recognises the importance of problem solving techniques in science teaching and this has been stressed as important in an EC document (EC, 2007) promoting the value of inquiry-based science education (IBSE). Nevertheless, there is little evidence that IBSE and the associated problem solving, by itself, is seen as relevant by students, indicating the need for further considerations in addressing ways to make science education more motivational for students. Context-based teaching is seen as a meaningful step forward in this regard (Gilbert, 2006; Gilbert, Bulte & Pilot, 2011), especially if these can be a pre-cursor to undertaking IBSE and allow science to be more meaningfully associated with environmental and everyday life issues (Estonian Government, 2011). This draws attention to the inclusion of both personal and social relevance within science education, amply expressed in an education through science view (Holbrook & Rannikmae, 2007). A context-based approach also recognises the need for personal intrinsic motivation driving the learning. Hence the value of initiating the teaching from a student relevance perspective before exploring the intended new science learning and then going further to apply the science learning in the social milieu, based on reasoned socio-scientific decisions. This approach can be meaningfully operationalized by means of a three-stage model (Holbrook & Rannikmae, 2010), as shown in the EU 7th framework PROFILES project (Bolte, Streller, Holbrook, Rannikmae, Hofstein, Mamlok-Naaman & Rauch, 2010).

In considering such paradigmatic changes, it is obviously important to reflect on the needs of science teachers and consider the type of professional development provision, which will enable teachers to reflect on their role in the science classroom. This need is felt, not only in the change of curriculum emphasis, but also in the need to keep abreast of new developments in the field of science and technology (NRC, 2010; 2012). To support teachers in a change of philosophy associated with the teaching of science and with this the teaching approach, it is important to reflect on teacher needs. Clearly, the more the teacher exudes self-confidence in the classroom, the more the students are likely to recognise the science education provision as promoting a coherent learning package, befitting the goals of science education and acquisition of the key competences. This provision very heavily relates to teacher confidence and competence in professional content knowledge (PCK) (Shulman, 1986), which can be viewed as a combination of subject content knowledge (CK) and teaching skills, based on professional endeavours. While CK relates to subject conceptualisation, PCK refers to the methodology in providing education to students, imparted in terms of promoting the key competences (Holbrook, Rannikmae &Valdmann, 2014).

To address teacher needs and to develop their self-efficacy in the classroom, teaching support is needed through the development of an effective professional development provision. However, research undertaken with science teachers has found that unless teachers really want to change, or really value how a particular change can make them and their students' experience something more worthwhile, they will not alter how they perceive themselves as science teachers, or radically change their practice (Simon, Campbell, Johnson & Stylianidou, 2011). With this in mind, the design of the professional development provision is important and besides addressing teacher needs, the effectiveness of the programme enacted requires careful consideration.

The aim of this research is to determine the effectiveness of an enacted professional development (CPD) programme, devised to address teacher identified needs, so as to promote more student relevant and motivational teaching-learning approaches.

The research questions are:

1. Can a CPD programme be designed to promote teacher's self-efficacy through meeting teacher needs related to adopting a 3-stage, 'education through science' teaching approach?
2. What indicators determine the effectiveness of such a CPD programme?
3. Which components of the CPD programme do teachers' value in raising their self-efficacy?

Theoretical Background

The 3-Stage 'Education through Science' (EtS) teaching/learning model

This model seeks to promote students' intrinsic motivation so as to stimulate them to become more interested and engaged in the learning of conceptual science ideas and, in particular, to relate inquiry learning to a science education which promotes intellectual, personal and social competences (Holbrook, 2008; 2010; Holbrook & Rannikmae, 2010; 2014).

The first stage is based on the need to promote intrinsic motivation, theoretically underpinned by Self-Determination Theory (SDT) (Deci & Ryan, 1985) and the importance of emphasising intrinsic motivation, above and beyond the extrinsic motivation largely promoted by the teacher. In this initial stage, learning stems from a

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real life, socio-scientific context, specifically intended to be motivational for students. The relevance and student interest are reflected in the students' active interactions, during which the teacher seeks to establish students' prior knowledge. Also during this stage the teacher leads students to put forward scientific questions for investigation, noting the additional intention being that students understand they lack scientific knowledge needed to explore more fully the context under study. When the teacher is able to undertake this effectively, the inherent student motivation to learn is expected to activate the second stage, also in a motivational manner. In this stage, the learning is decontextualized, enabling students to gain important scientific concepts through inquiry-based, student-centred approaches (Holbrook & Rannikmae, 2010; Holbrook, 2010). In the second stage, the teaching process is focused on delivering science education that goes beyond cognitive learning and promotes the gaining of educational competences, involving personal and social developments in line with 'education through science,' as opposed to the more traditional, science-only focus (Holbrook & Rannikmae, 2007; Holbrook, Rannikmae & Valdmann, 2014). The approach and hence the type of inquiry-based learning needs to relate to students' conceptualisation ability, albeit within the Zone of Proximal Development (ZPD) scaffolded by the teacher and fellow students (Vygotsky, 1978). Such learning is intended to promote problem solving (PBL) (Hmelo-Silver, 2004) encompassing planning skills, the development of science process skills and the ability to interpret findings relating these to other science conceptualisations. To consolidate the newly acquired conceptual science ideas and to re-focus on the initial relevant, socio-scientific context introduced in stage 1, the teaching proceeds to a further stage of learning. The purpose of this third stage is to strengthen further 'education through science' learning, especially in intellectual and social competences. This is so that students can make socio-scientific decisions; based on the development of well-reasoned argumentation skills (Toulmin, 2003) and, in the end, arrive at a whole class, consensus decision on the socio-scientific issue identified in the initial scenario (Holbrook & Rannikmae, 2010; 2014).

The Need to Promote Teacher Self-efficacy

An important role of teacher professional development is to raise both the competence and confidence of teachers. 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." Bandura also indicated that self-efficacy was malleable, could be changed given the appropriate environment and that self-efficacy beliefs were developed from four main sources:

- Enactive mastery experience
- Vicarious experience
- Social and verbal persuasion
- Physiological and affective states

Mastery experiences, the efficacy gained from an individual´s performance on a particular task, are seen as the most direct and most powerful source for the development of self-efficacy. Teacher self-efficacy is enhanced through enacting mastery when some form of self-reflection is included (Henson, 2001; Ross, 1994). Henson (2001) found that engaging teachers in participatory research improves teacher efficacy as it involved teachers in collaborative development with each other, as well as constructive interventions. Vicarious experience is more indirect and occurs when an individual observes someone else modelling a certain skill, or behaviour. It is most successful when somebody carries it out with similar abilities and attributes, such as age and gender. 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 enacted mastery experiences, while positively framed feedback in relation to goals has also been found to enhance efficacy (Bandura & Cervone, 1983).

The above is important and serves as a good platform for determining the effectiveness of the CPD. The first three components present a theoretical framework for improving teachers' self-efficacy so that teachers effectively promote the 3-stage 'education through science' model in the classroom. However, the physiological and affective state is the fourth factor affecting self-efficacy, because individuals have the capability to alter their own thinking and feeling. Fear about a successful outcome, for example, can lower self-efficacy perceptions and trigger additional stress and agitation providing a situation that can lead to inadequate performance. On the other hand, improving physical and emotional well-being and reducing negative emotional states can raise self-efficacy. Even more, enhanced self-efficacy beliefs can, in turn powerfully influence the physiological states themselves. Ross and Bruce (2007) 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 Importance of Teacher-Perceived, Valid and Reliable, CPD

Continuous professional development is shown to have a positive impact on curriculum and pedagogy implementation, as well as teachers' sense of efficacy and their relationships with students (Talbert & McLaughlin 1994; Craft, 2000). It can change teacher's beliefs and teaching styles (Bryan, 2012; Hofstein, Carmi & Ben-Zvi, 2003; Shahali, Halim, Rasul, Osman, Ikhsan & Rahim, 2015). In this regard, Desimone (2009) highlights five potentially key aspects of professional development: duration, active learning, collective participation, coherence, and content focus.

Programmes that last throughout the school year are shown to be more efficient than disposable one or two-day programmes (NRC, 1996; Lumpe, Haney & Czerniak, 2000; Brand & Moore, 2011; Posnanski, 2002; Gerard, Varma, Corliss, & Linn, 2011). In order to be effective, pedagogical development programmes are required to be active and practice-oriented (Day, 1999; Clarke & Hollingsworth, 2002; Lee, 2000, Kapanaze, Bolte, Schneider & Slovinsky, 2015). Active learning, as opposed to passive learning (typically characterized by listening to a lecture), can be undertaken in a number of ways. These can include observation of expert teachers, or being observed by others, followed by interactive feedback and discussion; and also by leading discussions (Baniloewer & Shimkus, 2004; Borko, 2004), as well as being meaningfully located in classrooms of other teachers (Putnam & Borko, 2000; Vaino, Holbrook & Rannikmae, 2013).

Joyce and Showers (1995) go further by showing that teachers are more likely to make changes in their practice if presentations and workshops are arranged such that the new skills are described and demonstrated, and teachers are given opportunities to reflect on their own performance. Collective participation can be accomplished through participation of teachers from the same school, grade, or department. Such arrangements set up potential interaction and discourse, which can be a powerful form of teacher learning (Desimone, 2003; Borko, 2004). Coherence is the extent to which teacher learning is consistent with teachers' knowledge and beliefs (Elmore & Burney, 1997; Bryan, 2012; Hofstein, Carmi & Ben-Zvi, 2003) and/or school, district, and state reforms (Fullan, 1993; Guskey, 1994; Penuel, Fishman, Yamaguchi & Gallagher, 2007).

The content focus of teacher learning can be the most influential feature (Desimone, 2009); linking those activities focus on subject matter content and its learning by students. With increases in teacher knowledge and skills, this can lead to improvements in practice and, to a more limited extent, increases in student achievement.

The Need for a Suitable CPD Model

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).

According to Howe and Stubbs (1997), a constructivist socio-cultural approach within a teacher PCK programme can be used 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.

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Research Methodology

General Background of Research

This research sought to determine the effectiveness of a specific teacher CPD programme, which was designed to prepare teachers to reflect on the goals of education and the manner in which the science curriculum can better be promoted. The CPD was based on a 3-stage, 'education through science' model addressing teacher needs related to an ability to enhance students' scientific and technological literacy (Holbrook & Rannikmae, 2007). The teacher needs were identified and addressed related to three aspects of teacher preparation i.e. the teacher as learner (focusing on subject content - CK), teacher as teacher (focusing on PCK) and teacher as reflective practitioner. The CPD was enacted using a constructivist, socio-cultural professional model approach (CSPM) as suggested by Howe and Stubbs (1997).

Sample

In total, 27 volunteer teachers participated in the CPD programme, with the following subject specialisations: biology (9), science (10), chemistry (7), and physics (1). The purposive sample was composed of female (26) and male (1) teachers, of which 22 taught in high schools (grades 10-12) and 5 in middle schools (grades 5-9); 14 had less than, and 13 had over, 21 years of experience.

Data Collection

Three instruments were used to obtain data on the effectiveness of the CPD programme during and/or after the CPD:

i. A validated Teacher Needs Questionnaire (TNQ).
ii. Semi-Structured Interviews.

Details of the 4-point Likert scale teacher-needs questionnaire (TNQ), indicating that the questionnaire measured self-perceived confidence (Cronbach $\alpha \geq 0.9$) and training needs (Cronbach $\alpha \geq 0.\ 9$), were described previously (Holbrook, Rannikmae & Valdmann, 2014). The instrument consisted of 10 subscales and including 52 items. In this study, the TNQ was re-administered to teachers in the last CPD session and pre- and post-CPD outcomes were compared.

Semi-structured interviews were held at the end of the CPD with 25 teachers. The same main question asked was: *"What aspect of the CPD helped you the most to understand and embrace the 3-stage EtS model in the classroom?"*

Data Analysis

Analysis of questionnaire data was undertaken using SPSS. The effect size for self-confidence and training needs subscales was determined using Cohen's d.

A semi-structured one-on-one interview was held with every teacher, each taking about 15 minutes. The interviews were conducted on two consecutive days under similar conditions. The interviews were recorded and the first author subsequently analyzed the transcribed interviews using qualitative content analysis. Nine teachers were approached a second time, by telephone, to validate their answers. Finally, two independent researchers validated the interpretation of the interview outcomes.

CPD Design

The planned CPD structure was based on findings from a previously administered, teacher needs questionnaire (TNQ) (Holbrook, Rannikmae & Valdmann, 2014) and teacher-learner developments, giving particular attention to:

a) Addressing an identified lack of confidence and competence in four TNQ subscales i.e. inquiry-based learning (IBL), assessment, reflection, and theories of education.

b) Introducing a 3-stage, 'education through science' teaching model (Holbrook & Rannikmae, 2010) and working through teaching/learning modules based on this model.
c) Teacher CK, PCK and reflective practitioner needs.

The underlying design for the CPD is shown in figure 1 and seeks to develop greater teacher self-efficacy in promoting the identified teaching goal of raising students' scientific and technological literacy (Estonian Government, 2011) based on an education through science construct. The underlying inverted triangle indicates teacher-identified learning needs, based on outcomes from the prior administration of TNQ (Holbrook, Rannikmae &Valdmann, 2014) covering aspects related to vision, operational skills and background ideas. The upright triangle completes the CPD model through the inclusion of three teacher-learning focus components, stipulated as teacher as learner (meeting science content learning needs), teacher as teacher (meeting teacher PCK needs) and teacher as reflective practitioner (meeting self-efficacy operational needs).

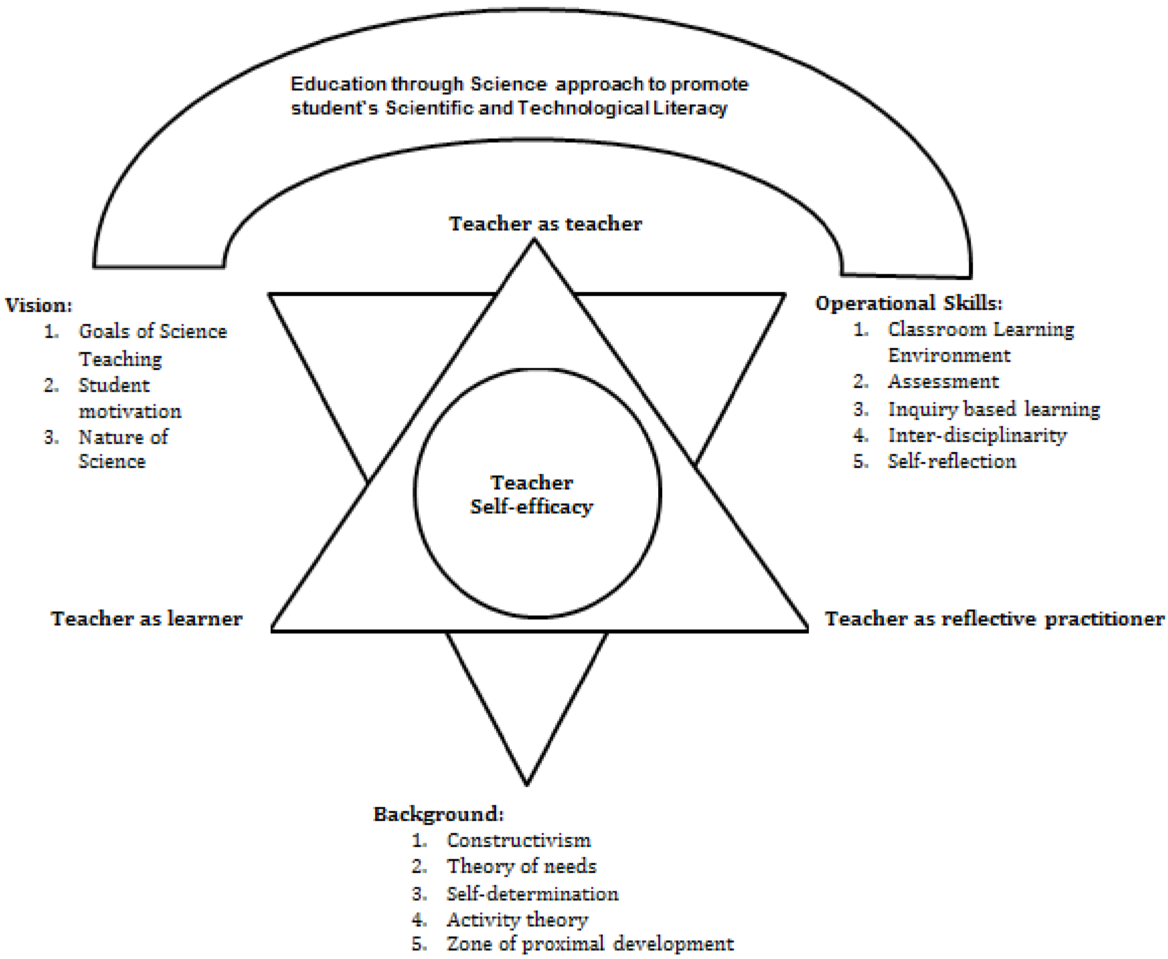

Figure 1: The underlying CPD design model promoting teachers self-efficacy.

CPD Planning

The CPD sessions were sequenced, but purposely spread across the school year (NRC, 1996; Lumpe, Haney & Czerniak, 2000; Brand & Moore, 2011; Posnanski, 2002), allowing teachers to try out ideas and to reflect on their

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learning. An intended theoretical outcome from the initial session was that teachers conceptualised the ideas behind the 3-stage EtS model.

The operation of the CPD was planned as presentations, workshops and seminar sessions (in line with the needs associated with the upright triangle in figure 1). Lecture presentations were included to enhance an interdisciplinary science background (new science content) as related to teaching modules used for driving intervention teaching-learning situations in the classroom between CPD sessions. The workshop mode involved teachers in various group activities, such as working through a module, undertaking the development of motivational scenarios, carrying out practical work and reflecting on the assessment strategy. This mode focused on the PCK learning within the 'teacher as teacher' component. The third mode, heavily stressed, was seminar presentations by teachers, where the teachers self-reflected on their teaching after trying out modules in the classroom situation. Here the focus was on the 'teacher as reflective practitioner' and

a) initially focused on a practical demonstration of activities in which experienced teachers could see how lessons unfold when used the 3-stage EtS model and how role-playing by participants could enable them to gain valuable vicarious experience.
b) 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 professional development provider and the whole group, following a CSPM design.

To support the ideas introduced in the CPD sessions, the first four seminar sessions introduced four teaching–learning modules specifically designed in line with the CPD intentions. Furthermore, each teacher was asked to implement different modules with students between sessions. The purpose of repeatedly trying out modules in the classroom situation was to give teachers valuable mastery experience. Feedback was obtained on the classroom interventions by means of written questionnaires completed by teachers and their students, encouraging teachers' power point presentations (a summary of the work of a specific module), as well as discussions in small groups.

CPD seminars, subsequently held after each intervention period, were planned to enable teacher professional interactions, sharing of best practices 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, the intention was to enhance teachers' self-efficacy through social and verbal persuasion (Bandura, 1997).

Modification to Plan

Although the CPD was initially planned as 4 sessions (two of which lasted for 2 days), after the third CPD session, it was found that teachers had difficulties in:

a) understanding the meaning and classroom operation of inquiry-based learning (IBL) and
b) 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 besides guidelines on how to create new modules (developing a motivational scenario and creating flowchart covering the use of the module). The final implemented programme was as illustrated in figure 2.

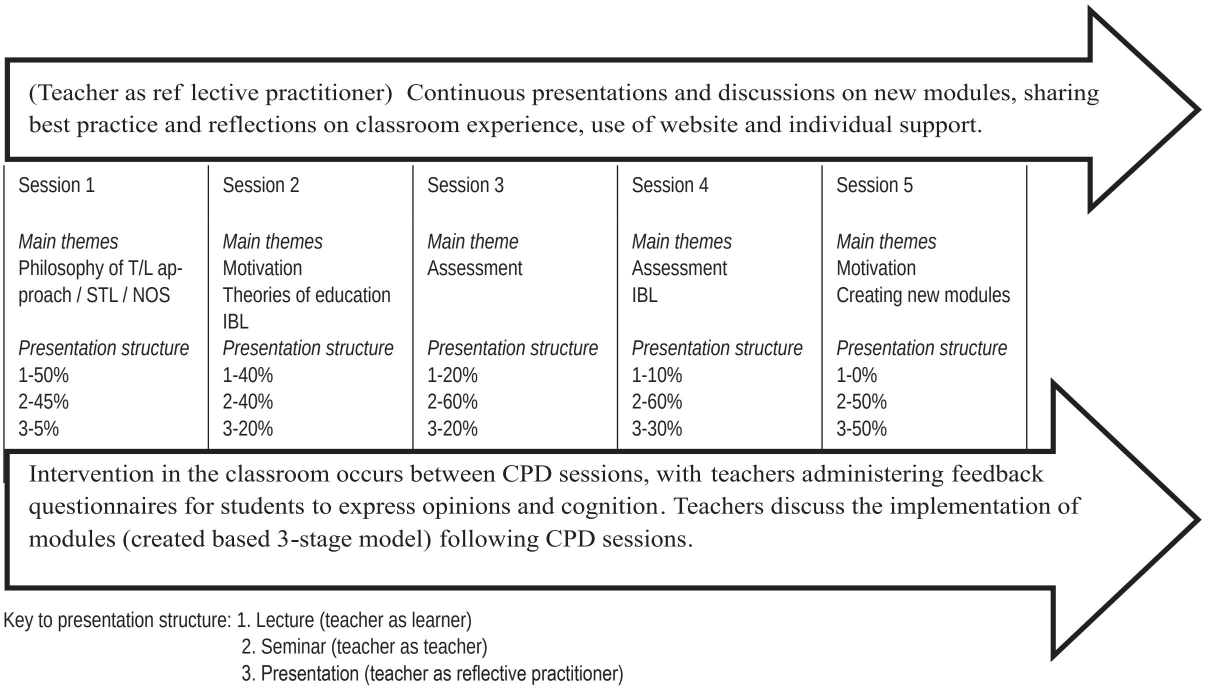

Figure 2: The enacted, modified CPD programme indicating the main themes per session and the breakdown of each session structure.

For the initial sessions, the emphasis of presentations was on content ('teacher as learner') and pedagogical knowledge ('teacher as teacher'), which were intended to answer the question; what to teach and emphasise? 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 top arrow indicates activities (discussions about new modules and learning-teaching materials, sharing best practice, reflecting on own classroom experiences, listening to interdisciplinary lectures and offering website and individual support to teachers) that took place throughout the training period. The lower arrow indicates the continuity of actions between sessions and the interactions, which then followed in subsequent sessions. Each teacher was expected to try out at least four modules during the academic year and provide written feedback.

Results of Research

i. *From the Re-administered TNQ*

The pre- and post-test (TNQ) questionnaire outcomes were compared in 2 ways:

(a) Change in teacher's self-confidence.
(b) Effect of the CPD components on lowering teacher's CPD needs.

a) *Teacher's Self-confidence*

Changes in the mean ratings for the teacher's self-confidence are given in table 1. Table 1 shows that the effect size (Cohen's d) is mainly greater than the standard deviation for both the pre- and post-test components, with the smallest effect size associated with the sub-scales motivation and interdisciplinary.

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Table 1. Pre- and post-test self-confidence (SC) and training needs (TN) responses determined in terms of effect size (Cohen's d) and significance of differences (Wilcoxon Signed Rank Z score).

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

**p ≤.05, **p ≤.001 Response scale: 1- not at all, 4 – definitely SD = standard deviation*

The major significant mean differences between pre- and post-test outcomes, based on self-confidence, were in the subscales:

- Goals of education;
- Inquiry-based learning;
- Learning environment, and
- Theories of education.

Significant mean differences between pre- and post- test TNQ related to confidence were not found in the case of two of the subscales: motivation and interdisciplinary. Similarly, the content of the modules, being supported by interdisciplinary lectures from scientists, was not associated with an increase in self-confidence.

b) *Meeting Training Needs*

The results given in table 1 also indicate that the teacher training needs decreased after the CPD programme in all ten subscales and significant mean differences between pre- and post-test data were found in all subscales,.

Table 1 showed that the effect size was greater than the standard deviation from the mean in both the pre- and post-test for most components, with the smallest effect size associated with the components, inter-disciplinarily and motivation. Interestingly, the largest effect sizes were for theories of education and IBL.

ii. *Semi-Structured Interviews*

Semi-structured interviews were held at the end of the CPD with 25 teachers based on the question: *"What aspect of the CPD helped you the most to understand and embrace the 3-stage EtS model in the classroom?"*

Key outcomes were seen as:

(a) Teachers feeling the need to be involved in reflective group discussions to share best practices (20 out of 25 teachers)
Some example comments made by teachers were:

1) *When we discussed how we used the modules during the seminars, I got good ideas/advice (tips). I had a problem how do assess students and I found a good solution –using student portfolios. I had not used this method before; other teachers introduced me to using portfolios. I tried and it worked. It seemed to me that the students liked to prepare portfolios. To me, it gave a good overview of what my student had learned and students were satisfied that they got only one mark, usually good (Teacher15)*
2) *I had recognized the difficulties of interpretation of experimental data. In the seminar, I shared my concern with the other teachers; we had a serious discussion and I received good suggestions for my problem.* (Teacher 24)
3) *In the workshops, I received many useful examples from colleagues on how to organize a good learning environment. I saw that other teachers had the same problems, and I felt I was not alone. It gave me confidence that I am able to move forward. (Teacher 27)*

(b) Working through a module from start to finish, with a view to understanding the philosophy behind the three-stage teaching model (18 out of 25 teachers).
Some example comments made by teachers were:

1) *"I did everything in the same way as our teacher trainer (I even arranged students in groups in the same way - this was for me a new idea and it worked well). I had all the time in my mind how I felt myself when I was a student, how I was learning and how our teacher only guided us (did not give answers). Many ideas were gained on how to manage a group discussion. I felt that 'playing through' the module gave me confidence to try out modules with my students, thus reducing my fear as to whether I could do it." (Teacher 3)*
2) 'Playing through' the module gave me a better understanding of what and how I should handle the lessons in order to reach the desired learning results. I had a vision of what students must know (and how to measure pre knowledge), what problems might arise, and a good exemplar of how the teacher could solve problems. It was one thing to read or listen to new teaching methods and materials; it was another to see how it worked. (Teacher 5)
3) I liked this idea ('playing through' the module). Our trainer was very professional and this gave me faith this method was good and my students would be learn necessary things, not only content but skills which were needed for life. By being involved in 'playing through' the module, I felt the importance of motivation, student discussion and the possibilities to use hands on activity (inquiry learning) plus the teacher's role to guide it all. (Teacher 6)

(c) Lectures, connecting with gaining interdisciplinary knowledge, being seen as important (15 out of 25 teachers)
Some example comments made by teachers were:

1) *I studied chemistry at the university. The modules were interdisciplinary content and I feel that I had a lack of knowledge of biology. Unfortunately, all the lectures did not support the content of the modules, I expected more. The first lecture was very good. (Teacher 12)*
2) *The modules were linked not only to the natural sciences but also implied a knowledge economy, social and ethical issues. I felt insecure about addressing these issues, and I thought the lectures were useful. (Teacher 22)*
3) *I am missing the interdisciplinary preparation. It is easier to start learning if the introduction made by a specialist. It is easier to search information if you have an overview of the problem. (Teacher 20)*

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Discussion

Table 1 shows that the mean effect size was positive comparing post questionnaire teacher confidence levels results with those from the pre-test for the same teachers. This indicates a positive input from the CPD, which is especially noted in promoting the learning environment and the goals of education. Interestingly, these components were not specifically addressed in the CPD, but the emphasis on involving the teacher in a student-interaction consideration linked to the classroom environment and the realisation of the purpose of teaching, promoted gains in confidence in handling the learning environment and relating to the goals of education.

It is worthy to note that the lowest gains were associated with promoting motivation and interdisciplinary teaching. It is suggested this can be explained by the high pre-TNQ scores, allowing little room for further gains in confidence levels.

Overall, the data seems to point to the TNQ identifying self-confidence needs and the CPD playing a positive role in raising the self-confidence levels for teachers. This suggest the TNQ is suitable for identifying self-confidence needs and that the CPD is effective in positively addressing these needs with respect to implementing the education through science, 3 stage model.

Table 1 also showed a similar pattern for increases in effect size in meeting teacher needs, while smaller increases were indicated again in motivation and interdisciplinarity. Greater increases were shown for theories of education and inquiry-based learning, which was seen as very encouraging in promoting the suggested effectiveness of the CPD. The appreciation of the theories of education was encouraging as this was seen as crucial for the paradigm shift in the teaching approach and the success of the education through science 3-stage model. Likewise, the success in meeting teacher needs for inquiry-based learning was very encouraging, inferring science teachers' interest towards greater student involvement in the thinking associated with the experimental experiences of students.

Teachers emphasize that being involved in reflective group discussions to share best practice was appreciated. The teachers were involved in planning from the onset (once teachers' needs were detected behind the three stage model. This is seen as reducing the stress of using a novel method by 18 out of 25 teachers.

Working through a module from start to finish provided an opportunity for teachers to monitor how the teacher educators promoted the various aspects of a module, this being seen as one way to gain vicarious experience. However, the teachers felt it was more than only observation: they felt they actively participated, as it was very much practice-oriented. Teachers considered working through a module from start to finish helped reduce the stress, expressed as physiological and affective states by Bandura as one source of self-efficacy beliefs.

A third valued aspect for the CPD highlighted by the teachers was need for interdisciplinary lectures, because the modules were seen as interdisciplinary and required extensive knowledge in different fields (biology, chemistry, physics) in order to feel confident and free in the classroom. The natural sciences evolved rapidly and it was difficult to keep in touch with modern scientific achievements. Lectures could 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 finding was in line with earlier research, which highlighted several aspects, that pedagogical development programmes needed to be active and practice-oriented (Day, 1999; Lee, 2000), reflective and collaborative (King & Newman, 2001; Clarke & Hollingsworth, 2002), involving the sharing of best practices (McLaughlin & Talbert, 2001). Both (reflection of own teaching and sharing best practice) were part our CPD plan to support teachers as teacher and teacher as reflective practitioner.

Working through a module from start to finish was related to Bandura's *verbal persuasion* (positive feedback from peers increased self-efficacy) and a constructivist, sociocultural professional model (CSPM) in that the CPD built on prior knowledge and experiences gave time for reflection and revision and supportive social context, shared experiences and promoted the free exchange of ideas (creativity). Both aspects (observation and stress reduction) created preconditions for teachers to gain a positive experience so as to be able to implement modules in the classroom. Positive mastery experience was seen as the most important factor in increasing teacher self-efficacy (Bandura, 1997).

The teacher as learner aspect was seen as an important component in the CPD programme; teachers placed emphasis on the value of the interdisciplinary knowledge and lectures. This was collaborated by other literature findings; for example, Swars & Dooley (2010) indicated that a lack of science content knowledge in the wider socio-scientific focus might lead to a lowering of personal self-efficacy. It was also supported by previous research (Valdmann, Rannikmae & Holbrook, 2012).

Conclusions

The purpose of this research was to determine the effectiveness of an enacted professional development (CPD) programme to promote teacher's self-efficacy with respect to implementing motivational, context-based science teaching, based on an education through science, 3-stage model.

The devised CPD programme was able to significantly raise teachers' reported self-confidence in 8 of the 10 sub-scales and reduced significantly training needs in all 10 areas. Components of value to teachers within the 'teacher as learner' category were the interdisciplinary lecture presentations.

The indicators which determined the effectiveness of the CPD programme can be specified in the 'teacher as teacher' component, as the effectiveness of the CPD was significantly felt in all sub-scale areas, but especially for inquiry-based learning, theories of education and assessment.

For 'teacher as a reflective practitioner,' teacher interviews led to the conclusion that the importance of playing through the module and sharing best practice were two valuable components of CPD which raise teachers self-efficacy to use a new approach in science teaching.

The CPD programme components, identified as raising teachers' confidence the most in implementing MCST were: working through modules and the subsequent negotiation. 85% teachers indicated that role-play helped them understand the 3-stage EtS model, reduced anxiety in front of the new and the unknown and raised self-confidence. Four modules were introduced in the initial training, of which two were 'played through' in the training session (only 15% of the teachers chose a module, which was not 'played through'), 72% teachers found sharing best practice gave useful tips, as well as increasing self-confidence to make changes to modules based on students' interest and local background. 60% 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 (the majority of teachers taught one subject). This was seen as consistent with Bandura (1997) self-efficacy determinants (mastery experience, vicarious experience and verbal persuasion). For example, enacting the module from start to finish gave teacher vicarious experience, which in turn increased the probability that the initial contact with the modules for use in practice was positive. Positive mastery experience was seen as the main source to increase self-efficacy.

Limitations of the Research

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 and promote modules in their classroom and were willing to reorganise their teaching programme to accommodate this.

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