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DETERMINING THE EFFECTIVENESS OF A DESIGN–BASED, CONTINUOUS PROFESSIONAL DEVELOPMENT PROGRAMME FOR SCIENCE TEACHERS

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Abstract. *This research examined the effectiveness of a design-based, continuous professional development (CPD) programme intended to promote teachers' self-confidence and teaching reflection skills. The CPD was associated with teacher implementation of theoretically devised, motivational, context-based, inquiry teaching modules, based on a justified 3-stage teaching model. The CPD programme was devised from prior identification of teacher needs, using a validated teacher questionnaire (TNQ) covering subject and pedagogical content knowledge, as well as other literature-identified, desirable teaching attributes. The effectiveness of the CPD provision was determined through two approaches - by re-administering the TNQ at the end of the programme and identifying significant self-confidence gains through application of the K-means clustering technique, and was also by the range of teacher reflections in, on and for action, provided by teachers after using modules in their teaching. Each teacher's reflections were qualitatively grouped, based on comments made during a semi-structured interview about the teaching, opinions on students' learning and attitudinal outcomes. Findings suggested a strong correlation between teaching confidence gained from the CPD programme and the range of identified types of reflective skills mentioned during the interview, which provided the depth of feedback related to classroom teaching in implementing the modules.*

Keywords: *competence-based, continuous professional development, teacher reflection skills.*

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Introduction

Rapid changes within society demand changes in education. To meet such changes, education can be expected to undergo reform and accordingly, new curricula need to be developed. This is especially so in science education which aims to prepare scientifically literate persons who have competences to conceptualise the science, manage new technologies, are prepared for lifelong learning and who are capable of undertaking responsible actions within the society (Tytler, 2007; Holbrook & Rannikmäe, 2007).

A major international reform over the last decade or so is the goal of developing students' key competences (NRC, 2010; Eurydice, 2002; OECD, 2005), through a focus on science education for everyday life (Aikenhead, 2006) This view is strongly identified with a teaching shift towards a wide view of scientific literacy (Holbrook & Rannikmäe, 2009; Choi, Lee, Shin, Kim, & Krajcik**,** 2011; Roberts & Bybee, 2014), which aligns with competence-based curriculum developments encompassing the acquisition of knowledge, skills, attitudes and values (Eurydice, 2002; 2012; OECD, 2005).

To support the intended change in teaching, specific attention is paid to students' motivation (Osborne, Simon, & Collins, 2003; Bybee & McCrae, 2011), inclusion of a context-based teaching focus (Gilbert, 2006; Gilbert, Bulte & Pilot, 2011), inquiry-based learning (IBL) (Crawford, 2000; Hofstein, Carmi, & Ben-Zvi, 2003; EC, 2009) and argumentation and decision-making skills (Sadler & Zeidler 2005; Osborne, Erduran, & Simon, 2004). Efforts in supporting teachers in this direction have been the focus of two European Commission projects – PARSEL (Holbrook, 2008) and PROFILES (Bolte, Streller, Holbrook, Rannikmäe, Hofstein, Mamlok Naaman, & Rauch, 2012). In both projects, teachers are guided towards new approaches to science teaching using a 3-stage implementation model (Holbrook & Rannikmäe, 2010) and project, or teacher self-developed, teaching modules indicating the teaching approach. These were based on a philosophy, identified as 'Education through Science' (Holbrook & Rannikmäe, 2007).

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Following European initiatives, the Estonian Government (2011) implemented a new competence-based curriculum, in which Estonian teachers were confronted with the realisation that the new curriculum required a different approach to teaching. Osborne (2007) pointed out "Changing the curriculum was one thing, asking teachers to change their pedagogy to meet the demands of such a curriculum was another" (p.181). To support teacher change, much research drew attention to the importance self-efficacy played in developing the ability of a teacher to function effectively in the classroom (Bandura, 1994; Woolfolk Hoy & Davis, 2006). While knowing ones subject was seen as important and having a range of teaching skills was essential, dealing with changes that occurred in the education system and in teaching methodologies which were previously not essential, required the establishment of teachers' confidence so that they felt they were capable of handling the change, even if initial implementation met with reductions in the classroom climate. The need to facilitate an effective promotion of teacher self-efficacy, led to a need for greater attention to providing a professional development programme.

Although numerous CPD programmes have been developed, which focused on an in-service training model, or approach (e.g. Saunders & Rennie, 2013; Witterholt, Goedhart, Suhre, & van Streun, 2012; Brand & Moore, 2010; Dijk & Kattmann, 2007; Diaconu, Radigan, Suskavcevic, & Nichol, 2012), these programmes tended to lack a desired philosophical frame, based on specified teacher needs and often did not pay attention to post-CPD implementation. As an alternative approach, Kapanadze, Bolte, Schneider, and Slovinsky (2015) used a so-called 'stages of concern' model, grounded on philosophies by Fuller (1969) and Hall and Hord, (2011), through which they determined professional-oriented attitudes and concerns by in-service science teachers regarding inquiry-based science education (IBSE). However, this model is specific to inquiry based teaching, limited to comparing outcomes from a pre- and post- teaching concerns questionnaire and does not seek to address wider teacher needs associated with changes, such as conceptualisation of relevant educational theories, appreciation of the nature of science and science education (Holbrook & Rannikmäe, 2007) and the emphasis on addressing student motivational aspects.

There was thus a perceived need to develop CPD programmes, related to meaningful teaching philosophy and which promoted student motivational, teaching materials, also seen as curriculum relevant and motivational by teachers. To address these concerns, an authentic, continuous professional development (CPD) programme was specifically designed, based on teacher-identified needs for competence-based science teaching, as derived from responses to a validated questionnaire (Holbrook, Rannikmäe, & Valdmann 2014; Valdmann, Rannikmäe, & Holbrook, 2016). Besides addressing the identified teacher needs, the CPD also emphasised a competence-based, teaching approach through specifically designed teaching modules. The teaching modules were developed, in line with this CPD thrust, based on a literature reported, 3-stage model (Holbrook & Rannikmäe, 2010) seeking to give greater clarity to competence-based science teaching.

Clearly the effectiveness of the design-based CPD provision is important. Although steps have been taken to evaluate the effectiveness of CPD programmes (Desimone, 2009; Harland & Kinder, 2014; Whitworth & Chiu, 2015), these are limited in their philosophical approach and teacher identified needs. While the effectiveness of a CPD to raise a teacher's self-efficacy can be determined by means of a questionnaire, it is also important to ascertain the effectiveness of the design-based CPD in promoting a permanent change (Rannikmäe, 2001) in teacher classroom practices and event more to check on the manner in which the teacher has progressed to be able to reflect on their teaching and make adjustments in the light of concerns. The teacher's ability to be able to reflect on their teaching is thus an important aspect in identifying the teacher self-confidence of the philosophy, model and teaching approach so as to be able to effectively operate in the classroom as intended from the CPD provision.

The goal of this research study is to evaluate the effectiveness of a previously described, design-based CPD programme (Holbrook et al., 2014) intended to:

- raise teacher confidence in teaching, based on a previously reported 3-stage model;
- allow meaningful implementation of the philosophy promoted during the CPD using teaching modules based on the 3-stage model, and
- prepare teachers able to reflect on their teaching, based on the 3 stage, Education through Science model.

The Research Questions

1. Can the effectiveness of the CPD programme, based on teacher self-identified needs, be determined by increased teacher self-confidence and their subsequent reflection skills in undertaking competence-based teaching using teaching modules based on the 3-stage model?

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2. Can teacher self-confidence and reflection skills play a meaningful role in evaluating meaningful teaching, based on the 3-stage model?

Theoretical Background

Self-confidence

Studies show that self-confidence influences teacher' autonomous abilities in teaching (Spratt, Humphreys, & Chan, 2002; Benson, 2010; Harrison, Lawson, & Wortley, 2005; Paradis, Lutovac, & Kaasila, 2015). Self-confidence is defined within the literature as a positive/negative self-evaluation, or perception of the self (Chuang, Cheng, Chang, & Chiang, 2013; Tett & Maclachlan, 2007) and is usually related to the degree of certainty directed towards one's general capabilities, personalities or abilities (Morony, Kleitman, & Stankov, 2013). Thus, self- confidence relates to efficacy beliefs. The concept of self-efficacy beliefs proposes that the belief (confidence) in one's abilities (competence) is a powerful driving force that influences "motivation to act" (Bandura, 1997). Self-confidence, based on efficacy beliefs, derives from successful practice and positively received feedback. Furthermore, meta-cognition and reflection play an important role in the development of teachers' self-confidence to use new approaches and novel ideas, which are accepted and meaningfully applied in teaching (Kaune, 2006). In this study, self-confidence is used in order to evaluate the effectiveness of CPD programme in a new context i.e. the 3-stage "Education through Science" teaching model.

The 3-Stage 'Education through Science' Teaching/Learning Model

This model seeks to promote students' intrinsic motivation to stimulate greater interest and subsequent engagement 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 & Rannikmäe 2010; 2014).

In the initial stage (contextualisation) of the model, learning is based on a relevant scenario (real life setting), which is then intended to motivationally activate the second stage in which the learning is decontextualized, enabling students to gain appropriate scientific concepts through inquiry-based approaches (Holbrook & Rannikmäe, 2010; 2014; Holbrook, 2010). At this stage, the teaching is seen as aiming to deliver science education that goes beyond cognitive learning towards the gaining of educational competences, it needs to involve both personal and social development in line with the 'Education through Science' philosophy (Holbrook & Rannikmäe, 2007) as opposed to the more traditional science teaching through an introduction based on science content.

The purpose of the third stage (re-contextualisation) is to further strengthen the earlier 'Education through Science' learning enabling students to make justified, socio-scientific decisions through well-reasoned argumentation and, in the end, arrive at a consensus decision about the socio-scientific issue put forward in the initial scenario.

Reflection

Reflection is seen as an important component of professional learning and hence teacher development. Dewey (1933) defined reflection as the "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). Reflection is seen as a metacognitive strategy involving an active exploration of experiences to gain new, or greater, understanding. In addition, several researchers highlight the importance of teacher reflection when experimenting on new teaching approaches in professional development, which aim to develop teachers' beliefs and practices (Kaasila, Hannula, Laine, & Pehkonen, 2008; Kaasila & Lauriala, 2010; Clarke & Hollingsworth, 2002; Shulman, 1987).

Calderhead and Gates (1993, cited in Dana et al., 1997) suggest that the use of reflection in teacher education encourages teachers to take greater responsibility for their own professional growth, to acquire a degree of professional autonomy and facilitates teachers' development of their own theories of educational understanding and practice. Wenger (2005) contends that reflective practice helps teachers to focus on the complex, interactive relationship between practice and theory (p. 48). In Clarke's and Hollingsworth's (2002) interconnected model of teachers' professional growth, reflection is one of the mediating processes that connect beliefs and practices. Reflection is this seen as a meaningful way to help improve the teaching practices of veterans and novices, as well as

future teachers (van Es & Sherin, 2010; García, Sánchez, & Escudero, 2007; Kersting, Givvin, Sotelo, & Stigler, 2010; Moore-Russo & Viglietti, 2011; Freese, 1999; Sherin & Han, 2004; Moore-Russo & Wilsey 2014). This necessitates teachers questioning themselves about what, how and why they are teaching in a particular way based on defined objectives. It is not surprising, therefore, that reflection has an important place in many in-service programmes (Howe & Stubbs, 1997; Clark & Hollingsworth, 2002; Shulman & Shulman, 2004; Brand & Moore, 2011), thus helping to increase teachers' self-efficacy or change their beliefs and practice.

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. Thompson and Pascal (2012) claimed reflection-for-action was the process of planning, by drawing on experience and taking context into account. Regardless of whether the reflection was, at that moment, in the past, or about what might occur, at its most basic level the reflection was descriptive.

However, reflection could also 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 Larrivee (2008) suggested that reflection, as a critical component in its various forms, could actually be expressed at four levels (Table 1).

Table 1. Reflection viewed at 4 levels.

	Smyth (1989)	Larrivee (2008)
Level 1	Describing: (a) Describe/explain concrete teaching events. (b) Find the meaning of the event. (c) Provide an account of how the event happened as a basis for analysis	Pre-reflection in which the teacher is focused only on teaching.
Level 2	Informing: (a) Explore principles that inform classroom events. (b). Develop theories of teaching based on particular classroom situations (theory-in-use).	Teachers reflect about the effectiveness of their instruction.
Level 3	Confronting: (a) Ask questions about the theory, practice, assumptions, beliefs and values about teaching. (b). Situate the theory/ practice in broader social contexts.	Undertake reflection that enables being in touch with inconsistencies between espoused pedagogical theories and what is carried out in the classroom (theory-in-use)
Level 4	Reconstructing: (a) Take a position about the meaning of teaching. (b) Describe what action to take to change the situation.	Engage in critical reflection about the moral and ethical implications of one's teaching.

This research recognises that reflection can indicate much about a teacher's belief. The teacher's reflection skill can point towards the effectiveness of the CPD in guiding teachers to reflect on their change of beliefs, associated with acceptance of the 3-stage model as a way to promote competence-based science education. It is accepted that meaningful reflection can relate to the past, the present, as well as the future and, hence, give insights into a teacher's width of vision. The research thus recognises that it is useful to interrelate the three reflection types (reflection in, on and for) with the four reflection levels (describing teaching events, instructional effectiveness, questioning interactions, critically reconstructing) as a means of identifying teacher CPD gains and hence an indicator of its effectiveness.

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Research Methodology

This research was carried out to determine the effectiveness of a teacher CPD programme carried out within a European Commission project (PROFILES), based on teacher self-identified needs, to promote competence-based science teaching through the use of a teaching/learning modules, based on the 3-stage model. For this research, 16 teaching modules were utilised, or created, by teachers for use in the CPD programme, which extended over a 1 year period covering 40 contact hours.

Sample

In total, 27 volunteer science teachers agreed to participate in the longitudinal CPD programme. This purposive sample was composed of female (26) and male (1) teachers, of whom 22 taught in high schools (grades 7-9; 10-12) and 5 in middle schools (grades 7- 9). Among the teachers, 14 had more than 21 years of teaching experience, whereas the other 13 had a less experience.

The sample is not representative, but purposeful in the sense that it included very experienced and less experience teachers, teachers teaching at both basic and upper secondary school level and teachers exhibiting differing degrees of self-confidence in their own ability to promote student motivational teaching. However, all teachers in the sample were willing to try out new ideas and to discuss between themselves about teaching approaches.

For this form of research, it is clear teachers need to be volunteers and feel they want to participate. While the degree of success is likely to be higher than that from teachers as a whole, the diversity of the sample is expected to lead to degrees of self-confidence following the CPD and a range in the effectiveness of teaching using the approach being promoted. In this way, the effectiveness of the CPD can be considered.

Instruments

Three instruments were used:

1) Previously published pre- CPD questionnaire (Holbrook et al., 2014) and post- CPD questionnaire results (Valdmann et al., 2016) on the Teacher Needs Questionnaire (TNQ) are used in this study to develop the teacher self-confidence clusters. The validated TNQ consisted of 10 subscales (Appendix 1, 2). The participating teachers were asked to separately rate their self-perceived confidence (internal consistency shown by Cronbach α=0.95) and in-service preferences (Cronbach α=0.98) using a four-point scale in each case (1 – not at all; 4 – definitely).

2) Three questions were developed for a semi-structured interview. These questions, pertaining to the 3-stage model, were:
   (a) *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).
   (b) *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 question related to the teaching of the 2nd stage in the 3 stage model).
   (c) *How did you carry out the third stage decision-making*? What do you think went well? What problems did you encounter and what would you do differently another time? Explain?

3) 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 as given in table 1. Comments made by the teachers were applied to this reflection frame. in relation to:
   - 'reflection-for-action' (the reflection self-reported by teachers during the interview on their prior preparation);
   - 'reflection-in-action' (reflections with respect to the actual teaching as it took place), and
   - 'reflection-on-action' (reflecting with respect to the future)
   - (Schön, 1983; Killion & Todnem, 1991).

This allowed reflective comments by the teachers to relate to their teaching preparation, the teaching in ac-

tion and reflections that pertained to future teaching. The frame was further extended so that teacher reflections were captured for each of the three stages in the 3-stage model driving the teaching approach.

Data Collection

The TNQ was re-administered to the teachers (n=27) during the last CPD session, allowing pre- and post-questionnaire data to be obtained for comparison. This enabled the determination of changes in the teachers' self-confidence after the CPD had been completed. At the same time (in the last CPD seminar), a semi-structured interview (n=27) was carried out. In this research, the teacher responses to semi-structured interview questions were used for triangulation of the TNQ self-confidence clusters.

Data Analysis

Pre- and post- TNQ (Valdmann et al., 2016), were analysed using K-means clustering, to identify changes in self-confidence.

All reflective comments from the semi-structured interviews were analyzed using a literature-based reflection frame, as amplified in table 2. 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 divide into twelve levels, based on Table 2. These responses were compared and discussed to ensure their mutual understanding.

Table 2. A literature-based reflection frame used for analysing teachers' semi-structured interview responses.

	Guidelines for Reflective Comments / Reflective Comments at a Productive Level (Fund, 2010; Davis, 2006)			
Levels of reflection (Smyth, 1989; Larrivee, 2008) / **Types of reflection (Schon, 1983; Killion & Todnem, 1991)**	**Describing comments (L 1)**	**Effectiveness comments (L2)**	**Problems remaining (L 3)**	**Future considerations (solution) (L 4)**
	Answering to the question:	*Answering to the question:*	*Answering to the question:*	*Answering to the question:*
Reflection-in-action (R1) component	What was I doing (at this time)? (L1R1)	Was I feeling it was going to work (at this time)? (Perceived student reaction) (L2R1)	Was I feeling there was going to be problems (at this time)? (Difficulties perceived) (L3R1)	How was I thinking the problem could be reconciled? (L4R1)
With respect to Stage:				
1	*Re Q1 outcomes*	*Re Q1 outcomes*	*Re Q1 outcomes*	*Re Q1 outcomes*
2	*Re Q2 outcomes*	*Re Q2 outcomes*	*Re Q2 outcomes*	*Re Q2 outcomes*
3	*Re Q3 outcomes*	*Re Q3 outcomes*	*Re Q3 outcomes*	*Re Q3 outcomes*
Reflection-on-action (R2) component	What did I do before? (L1R2)	Did it work in the past? (L2R2)	What were the problem(s) I faced? (L3R2)	How to reconcile the problems for the future? (L4R2)
With respect to Stage:				
1	*Re Q1 outcomes*	*Re Q1 outcomes*	*Re Q1 outcomes*	*Re Q1 outcomes*
2	*Re Q2 outcomes*	*Re Q2 outcomes*	*Re Q2 outcomes*	*Re Q2 outcomes*
3	*Re Q3 outcomes*	*Re Q3 outcomes*	*Re Q3 outcomes*	*Re Q3 outcomes*
Reflection-for-action (R3) component	What will I do in the future? (L1R3)	How will I know whether it works in the future? (L2R3)	What issues might I still face? (L3R3)	How do I suggest to other teachers how to reconcile future problems? (L4R3)
With respect to Stage:				
1	*Re Q1 outcomes*	*Re Q1 outcomes*	*Re Q1 outcomes*	Re Q1 outcomes
2	*Re Q2 outcomes*	*Re Q2 outcomes*	*Re Q2 outcomes*	Re Q2 outcomes
3	*Re Q3 outcomes*	*Re Q3 outcomes*	*Re Q3 outcomes*	Re Q3 outcomes

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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.

Validity and Reliability

The outcomes from the K-mean clustering and the teacher comments inserted in the frame (Table 2) were compared to triangulate the teacher self-confidence, based on teacher self-responses to the TNQ and the level of comments made during the semi-structured interviews.

Interview questions were validated against the philosophy of the 3 stage model by 2 independent experts, as were the interpretation of Table 2. Teachers answers were categorised against Table 2 by two researchers in agreement 80%.

Research Results

Self-confidence Cluster Changes before and after the CPD Provision

To identify K-clusters, the mean values for the 10 subscales on the pre- and post-TNQ were utilised to form 3 clusters representing high, medium and low self-confidence groups in using the teaching approach advocated in the CPD. As the clusters were fairly well distinguished from each other, the three clusters approach was considered appropriate. In the pre-test interdisciplinary subscale had no significant influence in the forming of clusters (Appendix 1). In the post-test, all self-confidence sub-scales had a significant influence in the forming of the clusters (Appendix 2).

The change of self-confidence cluster groups by the 27 teachers, based on the pre- and post-test clusters, was as illustrated in Table 3.

Table 3. Self-confidence cluster changes from pre- to post-test.

Cluster	Pre-test No. teachers	Post-test No. teachers	
High self-confidence C1	3 →	3 (group 1)	} C1
	→	7 (group 2)	
Medium C2	7 →		
	9 →	9 (group 3)	} C2
	1 →	6 (group 4)	
Low C3	6 →	1 (group 5)	} C3
	1 →	1 (group 6)	

Key – arrows show teacher movement between clusters

Thirteen teachers moved to a higher self-confidence cluster based on the post CPD K-mean clustering, while thirteen remained in the same cluster. Only 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 group, fifteen and the lowest cluster, two teachers.

Teacher Reflection

Examples of teachers' reflections are presented in Appendix 3. The appendix describes teacher reflection categories (L1R1 ... L4R3) and examples are given, based on implementation of teaching modules developed using the 3-stage model plus teacher's self-confidence derived by means of the post-CPD cluster affiliation.

Reflections by the High self-confidence Cluster

Teachers from the high self-confidence cluster gave extensive reflective comments. Their comments covered all four levels (L1-L4), but were more related to reflections on problems remaining and future considerations. In fact, only teachers in this cluster group provided reflective comments in answer to the question: *How do I suggest other teacher be advised to reconcile future problems? (L4R3).* Also, as evidenced in Appendix 3, the comments of this group were related to all three teaching stages included within the modules and used in the classroom (i.e. to the contextualisation (stage 1), de-contextualisation (stage 2) and re-conceptualisation (stage 3) components).

The high self-confidence cluster group indicated:

a) A student relevant scenario was important for contextualisation.
b) Contextualisation needed to be related to students' age, prior knowledge and local circumstances.
c) More autonomy needed to be given to students in planning experiments during contextualisation and de-contextualisation.
d) Teachers needed to be more willing to include an open inquiry approach.
e) During re-conceptualisation teachers could guide student decision-making.
f) It was important to have a repertoire of good teaching ideas for the more difficult socio-scientific argumentation stage 3, such as role-playing, discussion sessions and holding a debate (Appendix 3).

Clearly, all 10 teachers were willing to adapt their teaching style. From reflections on how to deal with problems, they were more willing to embrace the 3-stage approach. They also expressed the desire to develop their own future teaching/learning modules and were willing to give advice to other teachers.

Reflections by the Medium Self-confidence Cluster

Teachers from the largest, medium self-confidence cluster also gave many meaningful, reflective comments. In many aspects, their comments coincided with those from the high self-confidence group, but it was notable that they did not provide comments to the question: *How do I advise other teachers to reconcile future problems?* (L4R3). Nevertheless, they were able to reflect on all three teaching stages. Two teachers from this cluster had previous teaching experience in using modules, based on the 3-stage approach (they previously participated in similar project) and perhaps, not surprisingly, all comments at the level of future considerations (L4R2; L4R1) were given by them.

This group of teachers mentioned that the main problem identified in stage 2 was that students were not strong in critically examining information and needed guidelines. The main problems encountered in stage 3 were that after interpreting experiment results, students were not interested to return to economical/social issues, presented in the initial scenario and teachers were not competent to guide students to incorporate social, ethical or economic arguments alongside those scientific.

Generally, teachers in this cluster gave competent comments on their actions in the classroom, but reflected less on the value of their actions compared to teachers in the high self-confidence cluster group.

Reflections by the Low Self-confidence Cluster

Teachers from this cluster gave fewer comments, found it difficult to be reflective 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 actions (reflection- for- action; R3). Also, they did not comment on stage three (the re-contextualisation stage in which the science gained was consolidated by relating to the initial scenario) and finished with interpretation of findings (which is part of the 2nd stage).

Discussion

It is generally recognised that CPD provisions for teachers, especially after curriculum or intended philosophical changes, are essential for successful implementation of an intended change of teaching direction and approach in the classroom. But the type of CPD needs careful consideration, if it is to be effective. From this research study, effectiveness is seen as being governed by:

a) Meeting teacher needs (in this case, for competence-based teaching) by promoting teacher self-confidence gains.

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b) Clearly indicating, in a participant-involved manner, competence in using teaching modules related to the changes; this shown through the diversity and levels of reflective perceptions put forward on the teaching enacted in the classroom.
c) Ensuring teacher self-competence in handling the scientific concepts involved from enacting student-centred, problem solving learning (in this case related to stage 2 of the 3-stage model).
d) Teacher acceptance of the proposed philosophy-and approaches, which are directly related to teacher confidence in the educational changes being advocated (in the case, competence-based teaching modules based on a 3-stage model).
e) Recognition, by the proponents, that the CPD model needs to be applicable generally and be superior to other CPD models in relation to the change being promoted (i.e. competence-based teaching). Thus the CPD is seen as generally applicable and the model is not solely dependent on the specific theoretical aspects considered (in this case, all that is intended via the 3-stage 'Education through Science' model, although both are seen as key to promoting competence-based teaching in science subjects).

The research is based on a created CPD model (Holbrook et al., 2014) and seeks to show that the effectiveness of such a model can be determined from:

a) Consideration of self-confidence, and
b) The type and diversity of levels of reflection related to teaching advocated by the CPD model.

Recognising a growing need for teachers to be able to carry out change in their teaching, based on society needs, a unique CPD programme was designed (Holbrook et al., 2014), based on using a constructivist socio-cultural professional model (CSPM) suggested by Howe and Stubbs (1997). This constructivist CPD was specifically devised, based on teacher-identified needs for competence-based teaching and, in this specific case, on the research undertaken to operationalise a 3-stage model (Holbrook & Rannikmäe, 2010). To evaluate the effectiveness of the programme, the methodology used was based on self-identified teacher gains in their teaching confidence and teacher's reflection comments, following teaching based on the CPD guidelines. The teacher-needs component of the CPD was identified using a validated questionnaire (Holbrook et al., 2014) and the degree to which these needs were meaningfully addressed was a feature identified using a clustered analysis of teacher's self-confidence once the CPD had been completed. The early outcomes from the Teacher Needs Questionnaire (TNQ) indicated the CPD was effective in raising teacher self-efficacy based on a teacher perceived self-confidence increase plus teacher recognition that training needs had decreased (Valdmann et al., 2016)

In this research, high confident teachers signalled they believed in the 3-stage model and the related modules and saw these as useful tools to increase students' scientific and technological literacy (Holbrook & Rannikmäe, 2009; Choi et al., 2011). While the initial TNQ indicated some teachers had high self-confidence at the beginning of the CPD, nearly half the teachers indicated high self-confidence at the end of the CPD programme. Furthermore, 13 teachers showed growth in their self-confidence in implementing a teaching approach, based on the 3-stage model. This suggested the CPD programme was able to meaningfully support, or raise teachers' reported self-confidence in teaching science using teaching modules, based on the 3-stage model. The CPD programme was, therefore, judged as providing a useful and effective approach to promote competence-based teaching.

It was noticeable that teachers within the high and medium self-confidence clusters gave more productive reflective comments; they associated personal experience, practical knowledge, educational theory with professional development (Fund, 2010). They were able to take a position about of the meaning of teaching, describe action to undertake to change the situation (Smyth, 1989) and engage in critical reflection about moral and ethical implementation of one's teaching (Larrivee, 2008), which refer to changes in estimates of the teacher's beliefs and practices.

When implementing the 3-stage model in their teaching, low confidence teachers admitted they found the greatest difficulty in administering the third (re-contextualisation) stage, where the aim was to develop students' argumentation skills and decision-making techniques. In this, the research findings supported previous evidence that ethical dimensions within competence-based teaching are new and uncommon in science teaching (Jutunen & Aksela, 2014). This reinforces the value of determining teacher's self-identified need so that the CPD provision can seek to improve teaching and guide teachers to determine approaches to raise student's argumentation and decision-making skills (Laius & Rannikmäe, 2011). This is in agreement with previous findings (Valdmann et al., 2012), where science teachers professed difficulties with leading students' discussions and argumentation.

Lotter, Smiley, Thomson and Dickenson (2016) found that teachers' self-efficacy to use inquiry learning developed when teacher training programme emphases social construction of new knowledge and reflection. They found an association between teacher self-efficacy and teachers perceived level of school support. This is

reinforced by findings from this study where two teachers who formed the low self-confidence cluster reported that they suffered from a lack of school support. Such results were also seen to be in agreement with studies, which emphasised the importance of a positive school climate (collective efficacy) and the headmaster role in supporting teachers seeking to implement new ideas (Desimone, 2009; Bianchini & Cavazos, 2007; McGinnis, Parker, & Graeber, 2004; Fullan, 2007).

About Reflection Findings

The findings illustrated that teacher reflections provided valuable insights into their teaching and the manner in which teacher gain from the CPD programme were put into practice. In this study, types of reflection were considered from the perspective of reflection in action, reflection on action and reflection for action (Schön, 1983; Killion & Todnem, 1991) and the levels of reflection within these types, derived from the literature (Smyth, 1989; Larrivee, 2008). This provided extensive insights into the teaching undertaken by teachers following the CPD. As expected, the teachers varied in both the types of reflection put forward and the degree of level of insights into their teaching and students' learning. Teachers, effective in implementing the intentions put forward in the CPD programme, showed they were giving considerable thought to considerations of all aspects of the intended teaching and striving to promote competence-based teaching. This was very apparent in the decision making of values areas, which in the 3-stage model was specifically promoted in stage 3 and where careful consideration of new teaching approaches were included.

About the Self-confidence – Extensive Reflection Link

In this research, findings suggested a strong correlation between teacher self-confidence gained from the CPD programme, irrespective of subject teaching background, and the range of identified types of reflective feedback, based on classroom teaching undertaken following the completion of the CPD course. The research showed clearly a link between self-confidence gains and the extent and diversity of teacher reflections put forward and pointed to these aspects proving a meaningful measure of effectiveness of the CPD course.

Findings from teacher reflections supported the opinion that the CPD was an effective tool in raising teacher's self-confidence to motivate students and use inquiry-based learning (IBL), even though this was inconsistent with a previous study (Kask, 2009). In the earlier study, Estonian science teachers exhibited low awareness and skills about inquiry based learning (IBL). The reasons might be associated with the need for high self-confident teachers in seeking teacher change and showed an effective CPD programme could influence teaching reforms. Teacher reflections from teachers who had higher self-confidence indicated that they confided more in students and gave them greater autonomy to choose learning problem/task. Nevertheless, based on many teachers' reflections, teachers generally commented that students had difficulties to create inquiry questions and teachers were able to notice student problems indicating their increased awareness.

The outcomes from the research study support the consensus opinion that reflection helps teachers to integrate the pedagogical theory and professional teaching-learning materials with their own experience, thereby developing their own practice (Wenger, 2005; Fund, 2010 Kaasila & Lauriala, 2010; Clarke & Hollingsworth, 2002; Shulman, 1987). Also findings are in agreement with researchers who highlighted the importance of teacher reflection during a professional development program, undertaken to promote new teaching approaches aimed to develop teachers' beliefs and practices (Kaasila & Lauriala, 2010; Clarke & Hollingsworth, 2002; Shulman, 1987).

Teachers valued the initial scenario stage in the stage model from two major aspects: motivational for students and usefulness for evaluating student's prior knowledge. This was very consistent with the intentions of stage 1 of the 3-stage model approach (Holbrook & Rannikmäe, 2010). This also shows that in any professional development course there are components which most teachers are able to pick up. Based on the literature, these tend 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).

Conclusion

The CPD programme, based on teacher-identified needs, is shown to be effective in raising the teacher's self-confidence to use the 3-stage 'Education through Science' teaching/learning modules. Findings from teacher

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reflections supported the opinion that the CPD was effective in raising the self-confidence of the participating teachers to motivate students and use student-centred, inquiry-based learning. For the science teachers taking part in this research study, the most difficult stage in the 3-stage model is the last (de-contextualisation), where the aim is developing students' argumentation skills and decision-making techniques, as components of higher order learning skills associated with the promotion of a competence-based science teaching approach.

Findings suggest a strong correlation between the teacher's self-reported confidence following the CPD and the range of identified types and levels of reflective feedback, based on classroom teaching in implementing the 3-stage teaching/learning modules. The high self-confident teachers are able to give a greater number and a wider range of reflective comments. They exhibit the ability to analyse the situation, summarise the value of their actions and identify and analyse patterns, plus link theory and practice. This contrasted with the lower self-confident teachers who gave less reflective comments especially related to the decision making, 3-stage model and how to deal with perceived future teaching issues. The gains by the top self-confidence cluster group of teachers and the high range of reflective comments made related to prior preparation operation and future changes point to the effectiveness of the CPD.

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. These teachers were motivated to join the programme and willing to promote project-developed modules in their classroom and were willing to reorganise their teaching programme to accommodate this. Nevertheless, these volunteer teachers illustrated that teacher gains from CPD provisions can vary and that for those indicating high self-confidence, this tends to be linked to the ability to reflect on their teaching in multiple directions associated with reflections in, on and for the suitability of the teaching.

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Appendix 1. Significance Testing of Differences between Clusters centres for the K-means Three-Cluster Solution (pre-CPD questionnaire on self-confidence).

Variable	Cluster Mean Squared	Degrees of freedom	Error Mean Squared	Degrees of Freedom (N=27)	F Value
Assessment	1.591	2	.081	24	19.661**
Goals of Education	1.770	2	.062	24	28.714**
IBL	1.044	2	.076	24	13.709**
Interdisciplinary	0.719	2	.186	24	3.863
Learning environment	0.902	2	.049	24	18.274**
Motivation	1.110	2	.069	24	16.009**
NOS	0.521	2	.102	24	5.125*
Self-reflection	1.157	2	.096	24	12.014**
STL	0.747	2	.096	24	7.783*
Theories of Education	1.362	2	.134	24	10.154**

***p <.001, *p <.01 two-tailed*

Appendix 2. Significance Testing of Differences between Clusters centres for the K-means Three-Cluster Solution (post-CPD questionnaire on self-confidence).

Variable	Cluster Mean Square	Degrees of freedom	Error Mean Square	Degrees of Freedom (N=27)	F Value
Assessment	1.558	2	.052	24	29.860**
Goals of Education	0.663	2	.113	24	5.880*
IBL	2.597	2	.127	24	20.393**
Interdisciplinary	2.163	2	.140	24	15.461**
Learning environment	0.325	2	.049	24	6.610*
Motivation	0.442	2	.032	24	13.739**
NOS	0.538	2	.077	24	7.017*
Self-reflection	2.274	2	.080	24	28.508**
STL	.777	2	.047	24	16.562**
Theories of Education	2.037	2	.116	24	17.579**

***p <.001, *p <.01*

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Appendix 3. Examples of reflections.

	Reflective comments			
Levels of reflection (Smyth, 1989; Larrivee, 2008) / **Types of reflection (Schon, 1983; Killion & Todnem, 1991)**	**Describing (L 1)**	**Effectiveness (L 2)**	**Problems remaining (L 3)**	**Future considerations including solution (L 4)**
	C1- cluster 1 teachers C2=cluster 2 teachers C 3-cluster 3 teachers			
Reflection-in-action (R1)	***What am I doing? (L1R1)***	***Is it working? (Perceived student reaction) (L2R1)***	***Is there a problem? (Difficulties perceived) (L3R1)***	***How do I reconcile the problem for the future? (L4R1)***
Stage 1 *How do you motivate students?* (This was asked related to the implementation of stage 1 in the teaching approach).	I am trying to make sure students recognise the familiar issue. C3	I feel that presenting a scenario goes well and students want to know more about this theme. C3	When students are discussing the scenario, they are afraid to express their own opinions to the teacher or the whole class. It discourages discussion. C2	I feel it is important based on their comments to guide students to focus on scientific problems in a way that is related to everyday life and how it affects them personally, because they do not feel confident to use scientific terminology in everyday or familiar settings. C1
Stage 2 *How do you undertake inquiry-based teaching?* (About the teaching of 2-stage)	I make strong use of group work. C2	Students are seen to be more creative by looking for answers to unexpected experimental results. C2	Students are unable to deal with planning inquiry independently and I helped them by asking questions. C1	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
Stage 3 *How do you carry out decision-making?* (About the teaching of 3-stage)	I choose different approaches (debates, role play, and essay) in stage 3, when teaching science using different modules. C2	I notice, students willingly talk about the results of their work, and express their opinions. Consequently, this theme is interesting and necessary for students. C1	The problem is that after interpreting test results, students are not interested to return to economic/ social issues (based on the initial scenario). C2	In stage 3, the emphasis needs to remain on the science, noting how it functions in the face of economic and social demands. Next time, I intend to direct students to undertake a debate and find different resolutions by questioning. C1
Reflection-on-action (R2)	***What did I do? (L1R2)***	***Did it work? (L2R2)***	***What were the problem(s) I faced? (L3R2)***	***How I was dealing with past problems meaningful for the future? (L4R2)***
Stage 1	I used fragments of a movie for the scenario. C3	I noticed that the students regarded the scenario positively. They are interested in economic and multidimensional aspects at a national level – they ask questions in these areas. C2	I feel that I have not always been able to identify the students' prior knowledge, because the discussion after the scenario has been weak (usually cut short). C1	The scenario was not relevant for my students. Next time I intend to change the scenario to make it more motivational for students. I will use controversial problems and information technology (videos). C1
Stage 2	Students interact with each other in seeking solutions to science questions. C2	In general, reflective discussions during the experiment are seen as helpful in guiding students in being prepared for unexpected results in the future. C2	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	Open inquiry is best handled with small (when you have 12 – 16 students) classes, because the discussion part take a lot of time and other students (who had different problems) find it difficult to be involved in thinking about other problems. Next time, I will ask the headmaster to divide big classes into two groups. C1
Stage 3	This time I used an essay to determine how well students can make decisions and how good they are in argumentation. C2	Students were eager to participate in argumentation (sometimes even after the lesson) and develop decision-making skills. C2	Students do not have skills to make meaningful summaries. C2	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

	Reflective comments			
Levels of reflection (Smyth, 1989; Larrivee, 2008) / **Types of reflection (Schon, 1983; Killion & Todnem, 1991)**	**Describing (L 1)**	**Effectiveness (L 2)**	**Problems remaining (L 3)**	**Future considerations including solution (L 4)**
	C1- cluster 1 teachers C2=cluster 2 teachers C 3-cluster 3 teachers			
Reflection-in-action (R1)	***What am I doing? (L1R1)***	***Is it working? (Perceived student reaction) (L2R1)***	***Is there a problem? (Difficulties perceived) (L3R1)***	***How do I reconcile the problem for the future? (L4R1)***
Reflection-for-action (Guiding further actions) (R3)	***What will I do in the future? (L1R3)***	***How will I know whether it works? (L2R3)***	***What issues might I still face? (L3R3)***	***How do I suggest other teacher advice to reconcile future problems (L4R3)***
Stage 1	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	Observe the students' emotions more, so as guide them to be better involved in the discussion and in determining their prior-knowledge. C1	I feel that identifying a good scenario is still likely to be a problem. C1	In general, a relevant scenario is important and for this, the following need to be considered - student age, prior knowledge and local circumstances. C1
Stage 2	In carrying out stage 2, I need to take greater account of students' prior knowledge about science. C2	By giving more attention to teaching students how to evaluate information, I hope I can see whether students use sources that are appropriate. C2	Determining how much effort is important in getting students to progress towards more open inquiry approaches. C2	In general, collecting relevant and accurate information is important to plan an investigation, analyse the data and make conclusions. For this, the following need to be considered – access to information and establishing science questions and hypotheses. C1
Stage 3	Monitoring the progress of student using essays, mental maps and portfolios. C2	I let self-assessment and students evaluating each other in a group. C1	How far is role-playing the dominant approach to increase student engagement in socio-scientific issue. C1	Teachers feel it important to have a repertoire of good teaching ideas for the more difficult socio-scientific argumentation stage 3, such as role-playing, discussion sessions and holding a debate. C1

In the table: C1 – reflection by teachers in the post-test high self-confidence cluster (group 1 and group 2 in figure 3); C2 – reflection by teachers in the post-test medium self-confidence cluster (group 3 and group 4 in figure 3); C3 - reflection by teachers in the post-test low self-confidence cluster (group 5 and group 6 in figure 3). Where R1 is reflection in action: R2 is reflection on action and R3 is reflection for action. And level 1 is describing: level 2 is indicating effectiveness; level 3 is problems encountered, and level 4 is future considerations and moral/ethical aspects. And stage 1, 2 and 3 refer to the 3-stage model.

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