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Identifying teacher needs for promoting Education through Science as a paradigm shift in Science Education

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ABSTRACT: This paper identifies an 'education through science' philosophy for school science teaching at the secondary level and determines its interrelationship with approaches to student acquisition of key educational competences and the identification of teacher needs to promote meaningful learning during science lessons. Based on the philosophy, factors identified as integral to the PROFILES project (PROFILES, 2010) and aspects related to the teaching approach, the paper sets out to put forward areas of potential teacher professional need and plan for an effective continuous development (CPD) programme to promote teacher's self-efficacy in undertaking teaching through 'education through science,' as advocated in PROFILES. From a breakdown of desired students' learning and components related to teacher self-efficacy, the professional needs of teachers are identified by means of a validated Teacher Needs Questionnaire (TNQ), covering identified pedagogical content knowledge and philosophical expectations, together with follow-up interviews with selected teachers. The TNQ/interview outcomes were analysed and used to develop a continuous professional development programme for teachers. Findings show that teacher competences needs were mainly focused on educational theories, assessment, inquiry-based learning and self-reflection, while their self-identified, perceived need for professional development was much wider and support in all potential components were requested. The wide request from teachers made the planning of the CPD more difficult but the various components were interlinked with the competence requirements in the developed CPD programme.

KEY WORDS: education through science, key competences, continuous professional development, teacher needs.

INTRODUCTION

Science education, at the secondary level (grade 7 and above), is firmly included as a component of the education provision, virtually worldwide. However many curricula, and through perceptions held by the majority of teachers, science education is seen as building on logical positivism ideas (van Aalsvoort, 2004a) in propagating scientific information and concepts as a theoretical component on the one hand and an observational language

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on the other. This implies that science teaching is seen as verification of the observation of phenomena and its generalisation into theories, with these theories supported by further observation. There is a cycle of teaching, often promoted as hypothetico-deductive, about the rationality of already existing results, rather than new discoveries.

The term ‘Education through Science’ (Holbrook & Rannikmäe, 2007) is proposed as a philosophy, adopted within the PROFILES project, with an intention to develop a revised teaching-learning approach, geared to international trends in science education, educational realism and the development of key competences in students (NRC, 2010; 2012). In promoting more meaningful science education through ‘education through science’, a paradigm shift in education philosophy is intended (Holbrook, 2010). The approach to education through a “fundamentals based” (basic scientific ideas leading to those more complex) science curriculum, approached from a scientist’s point of view, is being challenged. Instead a frame of reference is taken, which relates to the issues and concerns of society (both present and futuristic), as seen as relevant and appreciated by students. However, just because something is related to everyday life does not automatically mean it is seen as relevant to students. The relevancy is likely to be linked to the immediate concern or issue of the society, expressed in the media and impinging on the students' daily life (Holbrook & Rannikmäe, 2010). The emphasis on issues and concerns is seen to be important. Education through science sees the nature of science education as based on (a) an appreciation of the nature of science, (b) on the development of the student both in terms of intellectual development and in terms of attitudes and aptitudes and (c) on society development linked to interpersonal relationships and in making informed socio-scientific decisions within society (Holbrook & Rannikmäe, 2007).

Yet as a philosophy, ‘education through science’ goes further. It recognises the need to undertake academic challenges, preparation for the world of work and the need to promote responsible citizenship (Fernandez, Holbrook, Mamlok-Naaman & Coll, 2013). It seeks to encompass key learning competences for education as promoted by the European Commission (European Parliament and Council, 2006) and thus provides a focus for the needs of students in learning ‘how to learn’ through the gaining of science and technology competences (accompanied by mathematical competences), interrelated with the importance of promoting social, cultural, entrepreneurial and digital competences through personal and social attribute development and the need to further enhance communication abilities in verbal, written, symbolic, graphic as well as digital aspects. In this, it contrasts with the more standard view of science education, with its focus on lessons labelled science and driven by the subject content. This alternative, rejected philosophy is labelled ‘science through education. Table 1 below attempts a comparison of ‘education through science’ linked to context-based teaching with ‘science through education’ – the alternative, more content driven science teaching.

Table 1. A comparison of ‘Science through Education’ and ‘Education through Science’ (adapted from Holbrook & Rannikmäe, 2007; Holbrook, 2009)

Education through Science	Science through Education
Learn to learn via the science knowledge and concepts important for understanding and handling socio-scientific issues within society and as a foundation for further study and lifelong learning.	Learn fundamental science knowledge, concepts, theories and laws as a foundation for further study and lifelong learning.
Acquire investigatory scientific problem solving skills to better conceptualise the science ideas and their interrelationship with socio-scientific issues within society.	Undertake the processes of science through inquiry learning as part of the development of learning to be a scientist.
Gain an appreciation of the nature of science and technology from cultural and society points of view.	Gain an appreciation of the nature of science from a scientist’s point of view.
Develop personal skills related to creativity, initiative, entrepreneurship, safe working, and attributes associated with employability	Undertake practical work and appreciate the work of scientists.
Develop positive attitudes towards science as a major factor in the development of society, cultural and scientific endeavors.	Develop positive attitudes towards science and scientists.
Acquire communicative skills related to oral, written and symbolic/tabular/graphical formats to better express scientific ideas in a social and cultural context.	Acquire communicative skills related to oral, written and symbolic/tabular/ graphical formats as part of systematic science learning.
Undertake justified, socio-scientific decision making related to issues arising from the society at the local, national and global level.	Undertake decision making in tackling scientific issues.
Develop social values related to becoming a responsible citizen and undertaking science-related careers.	Apply the uses of science to society and appreciate ethical issues faced by scientists.

It is proposed that the ‘education through science’ philosophy can be further elucidated through two further considerations:

a) Students’ learning targets.
b) Teacher professionalism needs.

a) Students’ learning target

Where the teaching approach focuses on the learning through the subject of science for all students, ‘education through science’ aligns itself with the enhancement of scientific and technological literacy (STL), integrating the learning associated with conceptual science and science processes with personal and social life skills, albeit that these can be heavily environmentally related (Bybee & Champagne, 1995) and also aligned with education for sustainable development (Holbrook, 2009). This view is thus strongly identified with a teaching shift towards a wide view of scientific and technological literacy (Roberts, 2007; Holbrook & Rannikmäe, 2007; 2009; Choi, Lee, Shin, Kim & Krajcik, 2011), which aligns this term with competence-based curriculum developments in which learning encompassing knowledge, skills, attitudes and values (Eurydice, 2002; 2012; OECD, 2005) and 21st century skills (NRC, 2010).

The STL approach can be expressed as ‘developing the capability to creatively utilise sound science knowledge (and ways of working), in everyday life, to solve problems, make decisions and hence improve the quality of life’ (Holbrook and Rannikmäe, 1997; 2009). This is based on teaching approaches that promote the acquiring of educational skills involving intellectual, attitudinal, communicative, societal and interdisciplinary learning. Noting a “relevance to society” focus of ‘education through science’, science education is perhaps more meaningfully expressed as a combination of science and technology education. After all, it is the technology that impacts on the daily life of the society and provides the relevance for the underlying science ideas (Holbrook, 2010). This STL approach (Holbrook, 2010) is thus towards:

(a) inclusion of issue-based, or context–based teaching as a major thrust to ‘set up’ the scientific problem to be investigated (Zeidler, Sadler, Simmons, & Howes. 2005);
(b) the need to go beyond scientific problem solving to also encompass socio-scientific decision making (related to responsible citizenry) (Holbrook & Rannikmäe, 2007);
(c) recognition that STL relates primarily to enabling citizens to effectively participate in the real world and is thus a social rather than solely an individual consideration (Roth and Lee, 2004).

Notwithstanding the above alignment of ‘education through science’ with STL, there are suggestions that scientific literacy, or STL as preferred here, should no longer be used in referring to science education

(Fensham, 2008). It is recognised that literacy, in this context, is far more than reading and writing and a suggested French translation was best considered as ‘culture’ (UNESCO, 1993). Yet for all that, STL does not have a precise definition and its popularity “could well be linked to the high status and priority that the literacies of Language and Number enjoyed in the 1990s” (Fensham, 2008). The danger of course is that even though scientific literacy needs to be promoted as a ‘basic level of learning’ in science, it can be interpreted instead as a ‘fully-rounded education’ with strong overtones of subject content. Further, as each purpose for science education can well have its own set of ‘scientific and technological literacies’, education through science is taken as the overall philosophy and thrust, while STL is related more to the teaching approach.

The shift in Europe is towards a competence-based approach to education (Eurydice, 2002; 2012), strongly endorsed by DeSeCo (OECD, 2005). This directs education, in an integrated way, to the promotion of key competences, not through single subject provisions, but through an interrelated education approach. It draws attention to the fact that the number of different teaching subjects intended in the school timetable is not a major issue; rather the focus is on how best to promote key competences among students, and with what emphasis in the education provision. Here deviations between countries can be expected, related to factors such as culture, career specialisation and the needs of society.

The science education provision in schools through science lessons is usually called science (or some sub-division of this) on the school timetable, but the actual student learning within an ‘education through science’ focus is towards the attainment of key competences, identified through STL indicators. Through this, science teaching attempts to promote a range of competences so that the total education provision (through all timetabled subjects), over the total school education, is focused on striving towards student attainment of all key competences according to determined standards expressed at various school grade levels (Eurydice, 2002). Of course, as the key competences are not expressed in detail, this allows for cultural, or society emphases to be promoted within any education system. The European Parliament and Council, (2006) sees the following key competences as the focus of student education (table 2).

The recommendation indicates that these key competences are all interdependent, and the emphasis in each case is on students acquiring capabilities in critical thinking, creativity, showing initiative, solve problems, handle risk assessment, make decisions, and constructive management of feelings. All thus apply to science teaching. Yet while the key competences provide an educational target, its purpose is not strongly

Table 2. Key Competences and their description

	Key competence	Description
1	Communication in the mother tongue	The ability to express and interpret concepts, thoughts, feelings, facts and opinions in both oral and written form (listening, speaking, reading and writing), and to interact linguistically in an appropriate and creative way in a full range of societal and cultural contexts.
2	Communication in foreign languages	Mediation and intercultural understanding. The level of proficiency depends on several factors and the capacity for listening, speaking, reading and writing.
3	Mathematical competence and basic competences in science and technology	The ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations, with the emphasis being placed on process, activity and knowledge and the mastery, use and application of knowledge and methodologies which explain the natural world. These involve an understanding of the changes caused by human activity and the responsibility of each individual as a citizen.
4	Digital competence	The confident and critical use of information society technology (IST) and thus basic skills in information and communication technology (ICT).
5	Learning to learn	The ability to pursue and organise one's own learning, either individually or in groups, in accordance with one's own needs, and awareness of methods and opportunities.
6	Social and civic competences	Personal, interpersonal and intercultural competence and all forms of behaviour that equip individuals to participate in an effective and constructive way in social and working life. It is linked to personal and social well-being. An understanding of codes of conduct and customs in the different environments in which individuals operate is essential. Also knowledge of social and political concepts and structures (democracy, justice, equality, citizenship and civil rights) which equips individuals to engage in active and democratic participation.
7	Sense of initiative and entrepreneurship	The ability to turn ideas into action. It involves creativity, innovation and risk-taking, as well as the ability to plan and manage projects in order to achieve objectives. The individual is aware of the context of their work and is able to seize opportunities which arise. It is the foundation for acquiring more specific skills and knowledge needed by those establishing or contributing to social or commercial activity. This should include awareness of ethical values and promote good governance.
8	Cultural awareness and expression	Appreciation of the importance of the creative expression of ideas, experiences and emotions in a range of media (music, performing arts, literature, and the visual arts).

identified. Communication competence, for example, both within a country and Europe-wide is obviously seen as important within multi-linguistic Europe, but its specifically identifiable focus within science teaching is not clarified. The National Research Council (NRC) (2010) rates communication within science teaching as complex, as it needs to interact, within the social environment, with the student having the "ability and willingness to cope with the uncertain, participate in persuasion and negotiation, and even instructing."

A more compelling argument related to the need to promote the key competences is afforded by considerations of the purpose of science education. Traditionally this has been to provide a base for further science learning for which a conceptual thrust is seen as important. However, the 21st century skills movement (NRC, 2010) has identified employability skills as a major educational focus, while recognising the need to prepare for responsibility, especially in the social arena and in a democratic society. Interrelated to this, the education through science philosophy sees the focus of science education in terms of intellectual development, development of employability skills and career awareness, as well as the socio-scientific functioning within the society, especially in terms of informed and responsible citizenship (Holbrook & Rannikmäe, 2010).

b) Teacher Professionalism

Teacher professionalism is a crucial element in seeing the 'education through science' philosophy being meaningfully implemented by teachers and student acquisition of the key competences. An important approach to promote teacher professionalism is through the development and enactment of professional development programmes. In determined the needs of teachers with respect to promoting key competences in students within the science classroom, it is important to reflect on the form of continuous professional development (CPD) appropriate for teachers who are involved in an 'education through science' thrust. It has been proposed that such teacher needs can be meaningfully identified through considering 3 sub-divisions of 'education through science' (Holbrook & Rannikmäe, 2007) i.e.:

a) the vision for science teaching to promote education through science;
b) the operational skills for science teachers in promoting key competences for all students;
c) the background required by science teachers in teaching to promote key competences.

The purpose and hence the goal of this study is to devise and promote a teaching approach firmly based on the intentions of 'education through science' using a specifically designed continuous professional development (CPD) programme, driven by teacher needs and related to both practical and theoretical aspects of teaching.

The research questions are put forward as

1. Can teachers' level of self-confidence and self-determined training needs be identified related to science teaching, based on the education through science philosophy, by means of a validated teacher needs instrument?
2. What CPD support do teachers perceive as needed, related to science teaching in promoting key competences, using an 'education through science' approach?
3. What emphasis is needed for a science CPD programme based on teacher views, in line with the promotion of key education competences through science teaching?

THEORETICAL BACKGROUND

To promote the 'education through science' philosophy, it is suggested that PROFILES science teachers are expected to possess:

A) A Vision for Science Education for promoting 'education through science'

This vision, simply put, is science learning which provides meaningful education (through science) as an approach to seeing the science lesson provision promoting the key competences and thus relating to an STL approach. To operationalise the 'education through science' philosophy, it is suggested that teachers are expected to be conversant with:

a) The goals of science education associated with education through science.
b) Student motivation for learning through science lessons.
c) The Nature of Science in the manner in which science is portrayed through science education.

Goals of Science Teaching

Science teaching in schools needs to be seen as an integral part of the education provision (Holbrook & Rannikmäe, 2007). This infers that, in a subject-oriented curriculum, each sub-division aspires to meet all the stated goals of education (the key competences European Parliament & Council, 2006). While the actual subjects put forward are not so crucial, they can be expected to play their part in fulfilling the educational needs. Bearing this in mind, Bybee (1993) suggested that the goals of science education can be expressed in terms of five major components that underline the organisation of curriculum and instruction:

1. Empirical knowledge of chemical, physical and biological systems.
2. Scientific methods of investigation.

3. Personal development of the student.
4. Career awareness.
5. Social development or achieving the aspirations of society.

Perhaps not surprising, these goals of science education strongly interrelate with the ‘education through science’ philosophy and STL aspirations. Unfortunately, the first component has all too often been taken as the major aim of science teaching with the canonical knowledge taught associated with the specific subject areas (chemistry, physics, biology). Nevertheless, in terms of key competences, the potential to provide input to at least the first five competences (table 2) can be realised using science knowledge as a meaningful context.

The second component encompasses the creative skills and techniques of investigation and activities of inquiry problem solving. As this component exists among all sciences, it has been taken as fundamental for the integration of the different subject areas. Again inputs can focus also on promoting at least the first five key competences.

Components 3 and 4 recognise that students are individuals and that science education can play its part in helping individuals aspire to a general education that is relevant to their development and aspirations and provides an awareness of career opportunities. Within these components, key competences 5-8 can be expected to be promoted.

The last component ensures science education plays a role in the development of persons able to integrate into the society and gain skills to function within the society, as society would intend e.g. science education in relation to cultural, environmental, political and societal understanding, awareness and values. Again, at least key competences 5-8 can be promoted.

DeBoer (2000) indicated a rather more detailed perspective, seeing the goals of science education expressed through nine categories. Considerable overlap occurs with the Bybee portrayal, specifically for preparing students for the world of work and being an informed citizen, but DeBoer also pays attention to including a historical perspective as well as including the teaching of science promoting cultural and social key competences. Furthermore, while an everyday life context for science teaching is seen as important, DeBoer indicates this should not be confused with simply possessing familiarity with technological applications. And while Bybee indicated the need for personal development, DeBoer amplifies on this recognising science as a way of thinking and hence knowledge which is generated needs to be valid, with students recognising the limitations of science. The nature of science is thus put forward as an important focus. DeBoer also suggests a need for the development of positive attitudes, supportive of scientific endeavours. Interactions with the offerings from the media are a well-recognised feature of the social dimension, but DeBoer also saw a need to recognise the technological dimension interacting with science (key competence 3). This suggests a need for students to be able to relate to the nature of technology and the interdependence of science and technology.

Once it is accepted that science education cannot be divorced from education itself, the philosophical emphasis can be determined by the intellectual, cultural and social needs of the society (meaningfully portrayed by the expected key competences). However, while the goals can be expressed in a variety of ways, there is always the need to reflect on the motivation of students enabling them to play a role in their self-determination, self-evaluation and even self-direction competences.

Student Motivation

There is little doubt that motivation plays an important role in learning and is thus a major consideration in the PROFILES project. It can promote both new learning and enhance performance of previous learning if students perceive the value of learning tasks (Barlia, 1999). While it is uncertain, in specific situations, whether motivation drives interest, or interest and relevance instigate motivation, student motivation is a powerful component in school education. Ryan and Deci (2002), in their self-determination theory, suggest motivation can be sub-divided into intrinsic and extrinsic forms. As extrinsic motivation of students is promoted by external aspects, it is very susceptible to the continuing impact of such external components (see section on the learning environment). An obvious example is the role played by the teacher and the aspects under the teacher influence such as students' attention, participation and follow-up.

On the other hand, intrinsic motivation is influenced by internal student matters, such as relevance, familiarity and prior interests. In appreciating relevance, it is important to identify the specific framework i.e. is it relevance with respect to:

(a) the individual student's expectation that it will be useful in their lives? (a meaningful or useful perception)
(b) a need to meet society's measure of achievement (an examination or assessment measure perception)?
(c) those nominated by society to speak on their behalf (i.e. the Ministry of Education)? (a curriculum perception)

For student intrinsic motivation, the first two are likely to play a major role and for these to achieve maximum relevance it would seem logical that they should converge. Relevance is also associated with familiarity. Students perceive that the learning relates to that with which the students already associate. This is very much the context of their everyday life, either by direct experience, or through an extension of this e.g. via the media. Thus such relevance, in the eyes of students, is seen as a major factor in approaches associated with an 'education through science' philosophy. Relevance needs embedding instruction inside a student-developed, need-to-know situation. "In such a goal-based scenario, teachers identify a specific set of skills (including intellectual skills) and "embed" this skills learning in a task, or activity that the student will find interesting and relevant" (Rannikmäe, Teppo & Holbrook, 2010). This is intended to apply to teaching advocated by the PROFILES project.

A major concern in Europe has been the issue of students taking up science and technology related careers (EC, 2004), which in turn is blamed, at least in part, on the abstractness, boring disposition and non-relevance of science being taught in schools (Osborne, Simon & Collins, 2003; EC, 2007). A key to addressing this is seen as giving greater attention in science teaching to student motivation, not only through making the learning environment created by the teacher more appealing (especially through greater student centred approaches), but also through the actual learning materials themselves. Rather than seeing the science learning as textbook driven, isolated and separate from other subjects, a more educational focused teaching approach is put forward which derives from a context base that is familiar and also relevant to students. Such an approach, promoted in PROFILES, is intended to raise interest in science for all students and the goal of such teaching goes beyond simply cognitive learning and seeks to enhance a much wider vision of scientific literacy.

Cavas (2011), quoting Tuan, Chin & Sheh, (2005), suggests five important factors for motivation in science learning. - student self-efficacy, value (relevance/usefulness) of science learning value, learning strategies, individual's learning goals, and inevitably the learning environment. She also suggests the classroom learning environment created by the teacher and the students' own self-disposition also impact on motivation. In addition, cognitive stimulation, or if preferred, a suitable challenge within the zone of proximal development (Vygotsky, 1978), can be added. The motivational, challenging style of teaching is grounded on both relevance with respect to the context and inquiry-based science education geared to problem solving in its widest sense and well-reasoned, decision-making, where the science being acquired is considered in a social setting. Such challenges, appropriately put forward, form a major focus for gifted students.

Noting an intrinsically motivational approach to science teaching can be based on three key components:

- familiarity/usefulness to the student;
- intimate involvement of the student in terms of meeting a challenge;
- curriculum relatedness,

this frame of reference can be promoted via a socio-scientific beginning (Holbrook & Rannikmäe, 2010). Rather than science conceptualisation being the organiser of the teaching at this initial stage, the starting point is a relevant socio-scientific aspect in the society (Marks & Eilks, 2009; Holbrook & Rannikmäe, 2010; 2014). In this case, relevance is seen as being associated with a familiar issue, or concern in which the students are likely to be involved, or through which the lives of the students are affected in some way. Thus at a beginning stage, science lessons focus on a socio-scientific relevant issue, concern, situation, engaging students in a desire for self-actualisation (Mazlow, 1979). The learning thus begins in the context of the society in which the students function. It is context-based teaching and learning. PROFILES modules seek to adopt such an approach,

Nature of Science (NOS)

Many researchers have recognised that an understanding of the Nature of Science plays an important role in the development of competence-based, science learning (DeBoer, 2000; Abd-El-Khalick, 2004: McComas, Almazroa & Clough, 1998; Lin and Chiu, 2004). The difficulty is that there is no specific description for appreciating the exact nature of science and it is not surprising, therefore, NOS within science education can be considered from different perspectives. Generally the expected perception to be portrayed is an image of science as tentative, not able to provide a definite answer, but bringing to bear reasoned argumentation on the science theories and methods related to the issue. This is seen as a key element of ‘education through science’ and contrasts with logical positivism that is likely to promote observations as the unbiased truth, models as portrayal of reality, laws as scientifically derived rather than merely a description of observations, and even terminology as definitions.

Koksal & Cakiroglu (2010) suggest, based on literature findings, that the nature of science, as a component of school science, is not understood well by students, teachers and teacher educators. They also suggest the nature of science needs to be recognised as a human endeavour (the human fallibility has been limited, but not entirely eliminated), tentative (subject to change, as the knowledge is not proven, but simply not falsified), empirical (based on and/or derived from observations of the natural world although these are theory-laden), include human inference (as distinct from observation), imagination, and creativity (putting forward explanations), and be socially and culturally embedded). In fact, the results of epistemological and educational studies indicate that commonly accepted aspects to teach about nature of science in formal education are:

1. Scientific knowledge is theory-laden.
2. Scientific knowledge is tentative.

3. Observation is different from inference.
4. Scientific knowledge is based on evidence and observation.
5. There is no hierarchy among hypothesis, theory and law.
6. Laws and theories have different roles in science.
7. Scientific knowledge is embedded in social and cultural context.
8. Science is a way of knowing.
9. There is no universally accepted one way to do science.
10. Creativeness and imagination are also important to produce scientific knowledge.
11. Scientist is not objective (McComas, 1998; Khishfe & Lederman, 2006).

Zhi & Siu (2013) recognise different views of science can broadly be seen in terms of logic-empiricism versus post-positivism, realism versus relativism, and traditional versus contemporary. The logic-empiricist, realist or traditional NOS views generally consist of beliefs that the goal of a scientist is to discover the truth in nature, there exist the scientific method, and scientific knowledge progresses by an accumulation of observations, etc. On the contrary, the post-positivist, relativist or contemporary views roughly refer to those originating in and after 1960s, comprising the arguments that theories are the result of creative work, a single scientific method does not exist; scientific interpretations depend on their prior knowledge and the prevailing research paradigm, etc. PROFILES teaching is expected to be strongly focused on modern views of the nature of science.

B) Operational Skills for science teachers in promoting key competences

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 (PCK). While CK relates to subject conceptualisation, PCK refers to the methodology in providing education to students, imparted in terms of promoting the key competences.

Teacher content, or subject matter, knowledge seems to serve as an important prerequisite in an ability to reflect on teaching experiences and develop pedagogical content knowledge (Loughran, Mulhall & Berry, 2004; van Driel, Verloop, & de Vos, 1998). 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.” Teachers need to build up their competence to appreciate the ‘education through science’ philosophy. But this is not enough. Teachers also need the confidence to use acquired ideas in their teaching. Of major important here is the classroom environment, heavily related to student motivation. With a more interdisciplinary approach, additional CK may well be a strong teacher need. A major focus for the CPD component within PROFILES is the development of self-confidence of teachers.

Classroom Learning Environment (CLE)

The ability of the teacher to interact with students and the guidance a teacher gives to students when accessing and utilizing resource materials is seen as crucial. The vision and skills must of course focus on the meaning of science education, the expectations of the curriculum, plus the needs of the students and other stakeholders. But the ability to stimulate student motivation as suggested by Cavas (2011) is also crucial if self-development, interest and self-management are to be intended.

The classroom environment, enhanced by the teachers’ sense of motivational self-efficacy, is expected to focus on ensuring:

a) the intended teaching outcomes cover all educational targets related to ‘education through science;’
b) the teaching promotes scientific higher order thinking skills;
c) the approach to teaching begins from a societal perspective, which is perceived as relevant to the student, or meeting societal needs;
d) constructivism learning approaches are promoted using a student participatory approach;
e) students are actively involved in carrying out activities, or tasks, which are related to the intended outcomes. The student activities include scientific problem solving and socio-scientific decision making;
f) the conceptual learning to be achieved can be summarised in a consequence map, although such creation can go beyond a simple concept map and encompass values education leading to socio-scientific decision-making;
g) a range of students’ communication skills (oral, written, symbolic, graphical, ICT) are promoted;
h) assessment is directly related to the degree of achievement of the intended learning outcomes specified.

The teaching approach, within an ‘education through science’ philosophy, is expected to rely heavily on student involvement. And, as there is a need to base the learning on prior constructs, often coming from society, the teaching approach is student driven. Nevertheless, there will be lessons where teachers lead the emphasis on acquisition of conceptual science ideas and students may require practice in skills of handling scientific data, manipulating variables, writing reports, or undertaking practise in other forms of reasoning skill development, or in the undertaking of calculations (classroom exercises). Importantly, it needs to be recognised that establishing situation interest, so as to strive for intrinsic motivation of students, is a useful, but insufficient condition (Rannikmäe, Teppo & Holbrook, 2010). It is suggested that the extrinsically motivating, teacher classroom learning approach, complemented by a student perceived relevance and usefulness, is much enhanced by the students' intrinsic motivation. A perceived goal for the classroom learning environment within the PROFILES project is strong extrinsic motivation by the teacher, providing meaningful situational interest for students, while the approach for a familiar and student relevant perspective, strives to promote and sustain students' intrinsic motivation.

Assessment

Assessment practices need to relate to the intended students' learning. They can encompass diagnostic assessment to guide the teacher, besides measures of attainment of the students in the various competence domains. Inevitably this means much of assessment related to 'education through science' is school-based and largely formative in nature.

Formative assessment is especially important as this can occur at all stages of teaching and be used to determine student achievement of all competences, or learning outcomes. As it is undertaken by the teacher to facilitate student learning, it can be teacher controlled in terms of when undertaken, on what learning attribute(s), with which students, in what manner and whether it needs to be interrupted to facilitate the need for teaching. It can also be recorded in a manner useful for the teacher. For example, in awarding a social value "score" (based on the learning outcome specified), the teacher can listen to the discussions by the various student groups and then award a "score" as follows (Holbrook, 2008):

x Has not made a meaningful contribution to the decision-making discussions. Is not able to decide, other than on economic grounds i.e. cheapest.

✓ Participates in the discussion and recognises that a choice can be made on scientific as well as economic grounds. Considers other factors e.g. environmental or social, when given guidance by the teacher.

✓ ✓ Plays a significant role in the discussions and reflect on many viewpoints from which a discussion could be made. Selects an appropriate choice based on social as well as environmental, economic and scientific grounds. Appreciates the disparity that may occur between the best choice and the actual practice within society.

In this 3 point example, clearly “x” indicates the competence, or learning outcome, is not achieved and more learning is required. The “✓” indicates the competence or learning outcome is achieved at a level identified by the teacher as meeting the standards at this stage of learning. The “✓✓” “score” is reserved for students achieving beyond the level intended and can be considered an important target for the more able students. By accumulating competence, or learning outcome “scores”, a meaningful guide to student's development related to a specific competence can be obtained.

Clearly frequent feedback in all learning areas associated with ‘education through science,’ from students to the teacher is important. With pencil and paper assessment limited in its coverage of more motivational or values oriented learning, the PROFILES project strongly promotes formative assessment undertaken by the teacher so as to better guide students and as a diagnostic indicator of the teaching approach.

Inquiry-based Learning

Inquiry-based learning has been strongly encouraged not only by the European Commission (EC, 2007) but also by most science educators, because students are provided with opportunities to ask questions, explore, plan, and most importantly, construct new knowledge and reflect on their learning (Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013).

Scientific learning experiences within an ‘education through science’ philosophy recognise the need to promote creative thinking, gain meaningful experiences and enable students to collaborate with others. This student-centred involvement is stimulated through an inquiry approach to science education (EC, 2007), although teachers can undertake inquiry learning with their students in different ways. The ultimate goal is to enable students to operate with no, or minimum, teacher support (i.e. students undertake project work or ‘open’ inquiry). For that, teachers will need to teach students to construct their thinking for the different stages of inquiry learning. And teachers need to realise that the more practice students have in inquiry learning, the more easily and the more capable they will be in undertaking high levels of student-constructed inquiry. In addition, in promoting ‘education through science,’ it is suggested that the following are all very much part of inquiry learning (although not actually seen as process skills):

- *identifying* the science in a socio-scientific situation;

– *putting forward* scientific questions (questions that can be investigated scientifically);
– if necessary, *breaking down* questions into sub-questions that can be investigated separately.

An example of the various attributes (and sub-stages) that teachers can consider in planning specific inquiry learning experiences for students is illustrated by Smith (2011), who in turn modified that by Herron (1971). He suggested that in very structured inquiry, the emphasis is conceptual and the student is involved in the interpretation or explanation of the inquiry findings. Far stronger learning takes place in guide inquiry learning although here the student can be engaged in different aspects depending on the leaning intended. However, teachers need to recognise that progression in gaining the various inquiry skills is not expected to be linear.

Dudu & Vhurumuku (2012) draw attention to school based inquiry being cognitively and epistemologically different from authentic scientific inquiry (research done by scientists), quoting Chinn and Malhotra (2002). It is noteworthy that the cognitive tasks needed for authentic science are more demanding than those required for school science. Epistemologically, school science has tended to be simple inquiry aimed at uncovering simple observable regularities, whereas authentic science aims at uncovering new theoretical models and revising existing ones. Clearly it is important that inquiry teaching is seen as part of the students' learning process. Dudu & Vhurumuku (2012) also note (quoting Vhurumuku, Holtman, Mikalsen, & Kolstoe, 2004) that school science learning activities as belonging along a continuum ranging from closed inquiry oriented to open ended of inquiry, where closed inquiry is characterized as teacher centred, expository, verification and related to a transmissive mode of learning. On the contrary, open-ended inquiry is learner centred and associated with such activities as: learners formulating their own problems/questions for investigation; offering alternative explanations to phenomena with outcomes of experimentation unknown prior to the inquiry process. The PROFILES project supports steps towards open-inquiry and suggests moves away from the use of standard worksheets, which tend to allow limited student creative thinking.

Inter-disciplinarity

Interdisciplinary teaching can be taken as an approach used to teach across different curricular disciplines, yet not always with the same meaning. In fact, besides the term inter-disciplinarity, terms such as multi-disciplinarity, trans-disciplinarity, cross-disciplinarity are also used (Mikser, Reiska, Rohtla & Dahncke, 2008). Dillon (2008) mentions that inter-disciplinarity is the most widely, but also the most indiscriminately, used term for breaking out of disciplinary boundaries, where inter- refers to between, among, mutuality and reciprocity. Multi-disciplinarity, on the other hand, is the juxtaposition of different disciplines, where multi- signifies combination. Strathern (2007) mentions that trans-disciplinarity not only disrespects disciplinary boundaries, but disrespects institutional ones too, but nevertheless notes that many understandings of inter-disciplinarity, in fact, substantially contain the characteristics of trans-disciplinarity.

A difficulty in science teaching is that the teacher conceptual science background has not kept pace with the changes and developments within society. Where the teacher lacks self-efficacy in an overall grasp of conceptual science, teaching is limited, leading to limitations in guiding any wide socio-scientific interactions with students. 'Education through science,' in promoting context-based learning and relevance moves away from the artificial subject division (e.g. biology, chemistry, physics) and hence relates to science and technology within the society. An important consideration is to ensure teachers can gain appropriate conceptual understanding to raise their self-efficacy for inter-disciplinary teaching. This aspect is recognised within PROFILES where the CPD model includes the 'teacher as learner' so as to better support teachers in gaining meaningful scientific background for interdisciplinary teaching,

Self-Reflection

It is important to realise that teaching is not about the teacher using suitable textbooks or teaching material, carefully compiled by experts and supplied to the teacher. The goal is that teachers are able to conceptualise the ideas and appreciate their importance in science teaching so as to promote the key competences. This suggests that an important teaching attribute is to enable teachers to undertake self-reflection on their teaching and perhaps even to encourage reflection among peers. Research evidence shows that even with a 6 months intervention study, many teachers are not able to fully grasp new science teaching ideas (Rannikmäe, 2001). If such teachers are then left to continue in their own way, most revert to their formal practices.

Professional development within the PROFILES project is intended to strongly promote self-reflection among science teaching by guiding teachers, through workshops, to utilise project modules and then to reflect on their experiences – the 'teacher as reflective practitioner' (Bolte et al., 2012). The workshops, following a planned model, introduce the 'education through science' philosophy to the participants, introduce teachers to science teaching/learning ideas, where a need has been identified and then guide teacher to adapt, or create their own materials, either individually, or as a group. Feedback on such experiences, encouraged within PROFILES during CPD sessions, leads to skills in self-reflection, which can be reinforced by group reflection on experiences gained and can even become part of an action research cycle (PROFILES, 2010). Learning by the teacher comes both from the experiences gained in the classroom, with the teacher guided to focus on the student competence gains and from the peer group interactions where suggestions for modification or alternative strategies can be put forward, allowing further self-reflection by the teachers involved.

C) The background required by science teachers for teaching

To complete the coverage of teacher potential needs, a third area of importance is considered. This is the needed teacher background based on theoretical considerations.

Constructivism

The ‘education through science’ philosophy and the STL approach are very much based on constructivist principles. Constructivism emphasizes the importance of the learner being actively involved in the learning process and that the need for students to build overt constructs, appropriate for learning, is at the very heart of such teaching. Such building is based on based on past experiences. Understanding is, at any given time, organized in the network of existing knowledge within the learner’s mind (Lutz, 1996). The constructivist teacher understands and uses constructivist principles by encouraging students to :

- reflect on their experiences and predict future outcomes;
- interact, both with the teacher and with one another;
- initiate learning and to develop leadership skills;
- respond and then the teacher adapts his/her strategy based on student responses;
- articulate their ideas and theories before requiring them to conceptual current thinking.

By embedding the science conceptual learning in a social issue, or concern and ensuring the science is seen as relevant in the eyes of the student, it is inevitable the teaching builds on students’ prior constructs, or ideas. As it is suggested that PROFILES advocates a teaching approach which makes students’ prior constructs overt, the project emphasises student involvement.

Theory of Needs

Maslow's hierarchical theory of needs (1943) towards self-actualisation is one of the most widely discussed theories of motivation. Self-actualisation is about the processes of what one does. As such, self-actualisers feel safe, calm, accepted and alive and share characteristics such as attempt to solve problems and pursue goals that are outside of themselves, are willing to take risks and experiment with their lives and they choose the direction of their own lives. They are thus both independent and resourceful. Self-actualisers are well placed to develop strong intrinsic motivation towards science learning given the appropriate setting and stimulus. It is proposed that self-actualisation is seen as an important need to be developed in students through PROFILES.

Self-Determination Theory (SDT)

Developed by Ryan & Deci (2002), SDT points to the importance of intrinsic motivation in driving human behaviour. Like Maslow's hierarchical theory, SDT posits a natural tendency towards growth and development, but highlights the difference between intrinsic and extrinsic motivation. The primary factors that encourage motivation and development are seen as autonomy, competence feedback, and relatedness.

In the school situation it is usual to strive towards stimulating students through extrinsic motivational approaches by the teacher. Such approaches tend to point to the logic of the subject, break down the learning to challenging, but manageable cognitive steps (within the zone of proximal development – Vygotsky, 1978) and offer stimulation to students through visual illustrations, opportunities for student involvement in the thinking and even direction of learning plus the use of a strong teacher control of a positive and stimulating classroom atmosphere. All this, however, is within the sphere of extrinsic motivation. All too often the missing element is the relevance of the learning in the eyes of the learner. This is a recognised concern in PROFILES science teaching, especially in de-contextualised, science conceptual learning situations, where the subject manner may have no apparent link with learning outside the science classroom. In striving for relevance, PROFILES sets out to promote students' intrinsic motivation, as well as enhance students' self-determination in science classes.

Activity Theory

In recognising the need to replace logical positivism, van Aalsvoort (2004a) proposes activity theory as the tool to address the lack of relevance of school science. This approach is strongly reinforced by Roth and Lee (2004). The theory is based on the interlinking of knowledge and social practice through establishing a need (relevant in the eyes of students), identifying the motives (wanting to solve scientific problems and make socio-scientific decisions), leading to activity constituted by actions (learning in school towards becoming a scientifically literate, responsible citizen). The activity model is appropriate for 'education through science' and, as suggested by Roth and Lee (2004), forms a theoretical base for developing scientific literacy, integrating the society need and the interrelated subject need.

In activity theory, activities constitute the unit of analysis (Roth and Lee, 2004) and the basis of the activity theory revolves around three levels of activity (van Aalsvoort, 2004b), namely:

1. the level of activity proper;
2. the level of actions, and
3. the level of operations.

The level of an activity proper can be interpreted as science-related practices so as to provide for student needs (as perceived by students insofar as this is possible, otherwise perceived by society as an area of need) and to do this in a more or less organized way by making ’products’ or ’decisions’ from ’raw materials,’ scientific components, or issues to resolve. At the level of actions, the division of labour, is the usual collaborative learning within groups which is the usual expected action within the classroom. The motive (wanting to decide), or the goal (learning how to decide) relates to deciding the most appropriate, justified choice, preferably taking into consideration the needs of all students or even members of the society. Operations concern the classroom techniques and established routines that are characteristic for the carrying out of the actions. In the classroom, these involve the plans and procedures for problem solving.

In Activity Theory, every activity has a motive that drives it. Thus in the activity of studying science, many different motives arise, some extrinsic to the activity (good examination outcomes, gain favourable teacher responses) and some intrinsic to the activity as to resolve the contextual issue by solving scientific problems. The activity is also composed of a variety of actions with their specific goals. For instance, to study science, there is the need to consult books, the internet, undertake experiments, etc. Every action has its own goal which, in isolation, does not allow understanding of the general school activity, but these actions, coordinated with several others, composes the science activity. However, in practice each action is, itself, composed of several operations, each with its specific material conditions for undertaking this operation. For example, the action of using the internet requires the coordination of computer access, locating appropriate sources, evaluating the source material, etc. These operations are subordinate to the material conditions, in the sense that they depend on the availability of the internet, etc. The activity thus includes different hierarchical levels (i.e. the activity, action and operation levels) and their feedback interactions. To understand the structure of an activity it is necessary to recognize the role of actions and operations, which only acquire sense if thought of inside the context of the activity (Rodrigues, Taveres, Ortega & De Mattos, 2010).

Activity theory very much applies to an ‘education through science’ philosophy and hence to PROFILES. Student activities are very much part of PROFILES science teaching, with student involvement in actions and operations linked to the wider student learning associated with the gaining of attributes associated with key competences.

Zone of proximal development

An ’education through science’ approach supports the relevance of building the learning from students‘ prior experiences in a constructivist manner, with students exposed to meaningful opportunities to construct their own meaning for learning. Such opportunities are afforded by students facing, and receiving adequately scaffolding for, appropriate challenges that fit within their ‘zone of proximal development’ (Vygotsky, 1978). Learners are constantly challenged with tasks that refer to skills and knowledge just beyond their current level of mastery when operating on their own, but which become achievable with the help of the teacher and/or peers. This captures their motivation and builds on previous successes to enhance learner confidence.

In PROFILES, it is expected that teachers provide students with intellectual challenges, especially as a way of raising intrinsic motivation. Clearly such challenges need to be do-able and thus within the zone of proximal development for students, working in a group, or for the individual students where self- development is intended.

Summary of potential teacher needs related to enacting ‘education through science’

In summary, identification of professional expectations among science teachers undertaking training to promote an ‘education through science’ philosophy with an STL approach such as in PROFILES, requires consideration of the following components as potential teacher CPD needs:

1. Goals of science education
2. Student Motivation
3. Scientific and Technological Literacy
4. Classroom Environment
5. Inquiry-based Learning
6. Assessment
7. Inter-disciplinarity
8. Self-Reflection
9. NOS
10. Education Theories

RESEARCH METHODOLOGY

The study reported here uses both quantitative and qualitative methods to determine a meaningful CPD programme, based on the ‘education through science’ philosophical needs of teachers. Quantitative data is based on the outcomes from administering a Teacher Needs Questionnaire. The qualitative data is based on the analyses of taped interviews, which were transcribed and reduced to indicate useful criteria.

Instrument: Teacher Needs Questionnaire (TNQ)

In this study, teacher needs are measured through self-confidence and in-service preferences. Self-confidence is seen as based on efficacy beliefs which teachers themselves feel they exhibit in practice (which received positive feedback). In measuring self-confidence, teachers undertake an evaluation of their skills, values, knowledge and attitudes.

Teacher perceived need for further training (training needs) were determined through self-indication and thus provided an indicator of teacher expectations. Positive indicators of training needs were expected to reveal a lack of competence, or perceived social pressure. In this study, teachers’ actual professional training needs were determined by comparing the teachers' self-confidence and their perceived training needs.

A Teacher Needs Questionnaire (TNQ) was devised through the following 3 step process:

- *Step 1.* This was an extensive review of theories and research related to teacher development, an examination of Estonian curriculum changes and identification of aspects associated with a motivational approach to the development of teaching –learning material. This step was based on an analysis of relevant literature and was undertaken to maximise the content validity of the TNQ, thus ensuring a sound theoretical framework (*see theoretical background*).
- *Step 2* involved writing individual items within subscales. Initially 92 items were identified, but on further validation by four experts from Tartu University, the number of items was reduced to 52, in these theoretical derived 10 subscales.
- In *Step 3,* six experienced science teachers were asked to assess the comprehensibility, clarity and suitability of items. The teachers evaluated each item and indicated whether the items were meaningfully representative of the corresponding subscales and whether they felt that the items were suitable and relevant; proposing, if appropriate, additional items. Items were modified based on these reviews.

The final 52 item questionnaire, developed, piloted and validated by experts as a pre-post instrument, covered was administered to volunteer teachers willing to participate in the PROFILES CPD programme (N=27) of which the subject specialisations were: biology (9), sciences (10), chemistry (7), physics (1). The sample was composed of female (26) and male (1), of which there were 22 were high school teachers and 5, middle school teachers; 14 had less than 21 years of work experience, while 13 had over 21 years and all held a Master's degree. The participating teachers were asked to separately rate their competence in terms of self-confidence (Cronbach α = 0, 95) and their professional training needs, i.e. whether they would like to receive training in this area, (Cronbach α = 0, 98) using a four-point scale (1 – not at all; 4 – definitely). Each of the 27 teachers responded to all items.

PROFILES CPD programme

Based on the findings from administering the TNQ, the CPD programme was devised covering 40 hours over one academic year as a combination of presentations, discussions and individual work. The programme was designed and validated with the guidance of 5 teachers who had earlier teaching experience with motivational inquiry-based learning and who had previously participated in similar training. The programme was planned to be supported by exemplary teaching-learning materials and aided by an intervention component, whereby the teachers tested the teaching-learning materials in their classrooms and reflected on the outcomes in small groups.

FINDINGS

1. Teacher Needs Questionnaire as pre-test

Mean values and SD for each of the ten subscales in the two sub-components, self-confidence and training needs were determined and mean differences calculated using Wilxocon Mean Rank test. Results are given in table 3.

Table 3 showed that the means for training needs were all above 3.0 and higher in all 10 subscales than the corresponding means associated with self-confidence in dealing with this attribute in science teaching. However, the differences in standard deviations across the sub-scales for both components indicate that there was a larger variation for training needs and hence more disagreement among the participants. In general, teachers had the lowest self-confidence for theories of education (m = 2,3) and self-reflection (m = 2,5) with the highest self-confidence in interdisciplinary learning (m = 3,2). Teachers placed the highest training needs in inquiry-based learning (m = 3,5) and somewhat surprisingly, in interdisciplinary learning (m = 3,5). The lowest support emphasis related to enhancement of the learning environment (m = 3,2) and appreciating the nature of science (m = 3,2).

Table 3. Univariate means and SD and mean difference between on the two TNQ sub-components.

Subscale	**Self-confidence**		**Self-perceived training need**		**Significance of Mean Difference (Z)**
	Mean	SD	Mean	SD	*p.05; **p.001
Assessment	2,6	0,44	3,4	0,59	-3,935**
Classroom learning environment	3,0	0,34	3,2	0,54	-1,766
Goals of education	2,8	0,44	3,3	0,57	-2,421*
Inquiry based learning	2,7	0,39	3,5	0,59	-3,891**
Inter-disciplinary	3,2	0,48	3,5	0,62	-1,797
Motivation	3,0	0,39	3,4	0,52	-2,535**
Nature of Science	3,0	0,37	3,2	0,51	-1,958*
Scientific-Technological Literacy	3,0	0,38	3,4	0,43	-3,118**
Self- reflection	2,5	0,42	3,3	0,67	-3,608**
Theories of Education	2,3	0,48	3,4	0,59	-4,272**

Significant mean differences were found in eight subscales. Although it was assumed that when teachers held high self-confidence, then they had low emphases for CPD, no significant correlations were actually indicated between self-confidence and course emphasis, suggesting that one or both sub-scales poorly related to self-efficacy, as intended by Bandura (1997). The emphasis on gaining more CPD, yet at the same time having high confidence, related to teaching with respect to the inter-disciplinarity, motivation and STL subscales, i.e. the teachers felt they were confident they could handle these aspects, but still wanted to further enhance their competence. At the other end of the scale, teachers held low confidence in theories of education, self-reflection, inquiry-based learning and assessment and subsequently recognised their need for CPD in these areas.

2. *Teacher Interviews to further identify and better understand teacher support needs*

To further consolidate the outcomes from the questionnaire, selected teachers were interviewed. During the focus group interview, teachers were asked to give their emphasis for a science education CPD programme. Findings from the 8 teachers in the interview showed that while a particular set of expectations were related to actual need for teacher training, needs expressed were also influenced by curriculum expectations, especially related to changes in the national curriculum towards competence-based education and also by a sense of curiosity (intrigued by what the CPD would entail). Taking curiosity as a personal aspect and curriculum impact as a social aspect, both unexpected influences offered explanations for the perceived discrepancies in high 'want,' but also high confidence. Examples of such comments are indicated below:

Teacher A: *These theories are all unknown to me, but I would like to know what they were and how to apply them in my work. (Unknown …stimulate curiosity) (Theories of education)*

Teacher B: *There's no video equipment in my school and I don't know how to use video equipment either, but it would certainly be interesting to see how a lesson went. (Unknown …stimulate curiosity) (Self-reflection)*

Teacher C: *I don't know what action research is, but I'd like to know. (Unknown …stimulate curiosity) (Self-reflection)*

Teacher D: *Formative assessment is a new topic in the curriculum. Everybody talks about it, but nobody knows how it could be operated precisely. (Changes in curriculum) (Assessment)*

Teacher E: *Under the new curriculum, gymnasium students need to conduct research and I need to be able to advise them. Inquiry learning is in the new curriculum, often said to be open, structured or guided. I want to be sure, that I'm doing everything correctly and in accordance with the national curriculum. (Curriculum requirement) (Inquiry-based learning)*

Teacher F: *Inter-disciplinarity is in the curriculum; it appears to us that we're doing it, but we would like more new connections and ideas; the topic is 'in the air;' the more we know, the better we can connect across the natural sciences. (Curriculum requirement) (Inter-disciplinarity)*

Teacher G: *As self-respecting teachers, how can we write that we cannot create a motivating learning environment? But then a small doubt arises that maybe it can still be done better; for that we need training. In the new curriculum much attention has been devoted to modern learning environments. (Curriculum requirement) (Learning environment)*

Teacher H: *If I've been trained, then I have the right to request from the headmaster, that she would buy new training tools; because I know how to use them and do not stay in school just to stand (Prove competency) (Learning environment)*

The results of the interviews suggested that teachers held the opinion that promoting interdisciplinary learning and ensuring a strong classroom learning environment are indicators of good teaching, and that a training certificate helps 'prove' competency (social aspect). Based on this, it can be concluded that the social aspect had an important role in defining training needs and that was a speculative reason for the lack of correlation between self-confidence and training needs.

In general, teachers' evaluation of their skills was shown to be unrelated to their request for training. The need for professional development seems to be more related to demands of society and personal curiosity. Thus the teachers do not seem to associate their skills and knowledge to relate to knowingly making progress. It would seem that teachers lack the ability to plan their own professional development. This, of course, makes planning an effective CPD course more difficult.

DATA ANALYSIS

For a more in-depth analysis, data was interpreted at the specific item level. To guide this, the following indicators were analysed:

(a) items indicating low confidence (m ≤ 2,5) (table 4);
(b) items for which teachers indicated high training needs (m ≥ 3,5) (table 5);
(c) using the Wilcoxon Signed Rank test, the biggest significant difference of means (Z value) between confidence and training needs were identified first by subscales (table 3) and second by items (table 6).

a. Self-confidence items which teachers rate the lowest.

Of the items indicating self-confidence, 9 items from 52 (table 4) had low mean values (m ≤ 2,5), Responses to formative assessment items – covering a rather new approach in Estonian schools as highlighted in the new Estonian curriculum (2011) – demonstrated the necessity of supplementary training. Teachers indicated low confidence in theories of education (four items) and assessment (two items).

Teachers' self-confidence is low with respect to items related to four Theories of Education items. Nearly half (14) of the teachers received their training during the Soviet era when the pre-service programme on the teaching of curriculum subjects had only one course on Education and Psychology. Emerging from the interviews (Valdmann, |Holbrook &

Rannikmäe, 2012), teachers indicated they would like courses in psychology, to better cope with the problems of the school, while on the other hand, teachers did not pay attention to a need for pedagogical theories. The teachers did not feel that pedagogical theories of knowledge helped them solve problems in school.

Table 4 Items with the lowest mean self-confidence (m ≤ 2,5)

Item	(sub-scale in brackets)	N	Min	Max	Mean	SD
Q42	Give meaning to ZPD (Zone of proximal development) (*Theories of education*)	27	1	3	1,7	0,71
Q43	Aware of SDT and self-actualisation (Maslow`s hierarchy) to motivate students (*Theories of education*)	27	1	3	1,8	0,62
Q47	Make self-reflective teaching videotapes (*Self-reflection*)	27	1	3	2.0	0,68
Q48	Use of action research to make teaching more effective (*Self-reflection*)	27	1	3	2,0	0,71
Q37	Undertake a range of formative assessment strategies with one`s own students (*Assessment*)	27	1	3	2,1	0,64
Q39.	I can assess students by means of their portfolio (*Assessment*)	27	1	4	2,3	0,72
Q44	Distinguish between intrinsic and extrinsic motivation of students (*Theories of education*)	27	1	3	2,3	0,61
Q46	Teach in a constructivist manner so that students are guided to construct meaning of knowledge (*Theories of education*)	27	1	4	2,3	0,73
Q16	Distinguish between structured, guided and open inquiry (*Inquiry-based learning*)	27	1	4	2,4	0,64

b. Items for which teachers indicated a high need for training.

Eleven of the 52 items received a mean rating greater or equal to 3.5 with respect to professional training needs (table 4), but Q16 and Q37 overlapped in also having a low mean self-confidence rating. Two of these items referred to aspects of inquiry-based learning and another two to student motivation – both sub-scale components seen as essential with relation to the new Estonian curriculum (2011) and both stressed as important Europe-wide (EC, 2007). In addition, two items related to student assessment.

Table 5 TNQ items identified as high training needs (m ≥ 3,5)

Item	(sub-scale in brackets)	N	Min	Max	Mean	SD
Q3.	Explain to students the difference between science and pseudo-science. (*NOS*)	27	3	4	3,5	0,51
Q9.	Direct students to use acquired knowledge and skills in new situations (*STL*)	27	3	4	3,5	0,51
Q16.	Distinguish between structured, guided and open inquiry (*Inquiry-based learning*)	27	3	4	3,6	0,50
Q17	Guide students to put forward scientific questions for investigation (*Inquiry-based learning*)	27	2	4	3,6	0,57
Q25.	Promote higher order thinking among students (*CLE*)	27	2	4	3,5	0,58
Q32.	Use of media texts and video clips to stimulate interest for students (*Motivation*)	27	2	4	3,5	0,64
Q34.	Encourage self-motivation by students in science lessons (*Motivation*)	27	2	4	3,6	0,57
Q37.	Undertake a range of formative assessment strategies with one`s own students (*Assessment*)	27	2	4	3,6	0,58
Q40.	I can write tests for students preparing to take into account the different levels of thinking (e.g. Bloom taxonomy) (*Assessment*)	27	3	4	3,5	0,51
Q41.	Promote student learning which focuses on storage in students long term memory rather than short term (*Theories of education*)	27	2	4	3,6	0,58
Q52.	Associate with new approaches to teaching science (*Inter-disciplinarity*)	27	2	4	3,5	0,64

The above suggests that teachers feel they do require additional training in the areas of assessment, student motivation and inquiry-based learning. Assessment consists of two aspects; one is formative assessment and the other test preparation according to the Bloom taxonomy. It is reasonable that the latter is connected to Q9 (use acquired knowledge and skills in new situations) and Q25 (promote higher order thinking among students). Student motivation and inquiry-based learning heavily relate to teaching in approaches in science subjects. It is noteworthy that teachers expect support from scientists to keep abreast of the latest achievements in science, in order to enrich the teaching of modern science discoveries (Q52) (which in turn they seem to perceive as related to student motivation).

Items 16 and 37 attracted low self-confidence and also a high need for attention during professional development. Kask & Rannikmäe (2006; 2008) noted in their research that Estonian teachers lacked understanding of inquiry-based learning and teachers didn`t distinguish open, guided and structured inquiry approaches. Both these aspects relate to the curriculum as well as having a Europe-wide emphasis and both heavily relate to effective use of the three-stage model in the teaching of science subjects.

c. Identifying additional teacher needs for a CPD programme

Based on outcomes from the TNQ, it was found that 14 items indicated significantly different means between self-confidence and training needs. Table 6 gives the means and standard deviations for those items where there were statistically significant differences between these two indicators (calculated using Wilxocon Mean Rank test). Considered at the subscale level, five items related to theories of education (80% of the total subscale items), two within the inquiry-based learning sub-scale (50% items), the self-reflection sub-scale (50% items) and the assessment sub-scale (40% items).

From these findings, a reasonable conclusion is that teachers felt that support in teaching was needed in the areas of: (a) inquiry-based teaching, (b) assessment, (c) self-reflection and (d) familiarity with educational theories. Furthermore, three items included in the educational theory sub-scale (Q42, Q43, and Q44) supported attention to student motivation (associated with providing a theoretical background to student motivation).

Identified teacher needs

Findings from teacher’s pre-intervention interviews and support TNQ outcomes indicated that teacher needs were particularly prevalent in five sub-scales: inquiry-based learning, assessment strategies, student motivation strategies, teacher self- reflection and knowledge of relevant theories of education.

Table 6. Significant mean differences between self-confidence and training need)

Items	(sub-scale in brackets)	Self-confidence M (SD)	Training needs M (SD)	Mean Difference (Z) p=0,00
Q3	Explain to students the difference between science and pseudo-science (*NOS*)	2,9 (0,58)	3,5 (0,51)	- 3,53
Q10	Refer students to a creative and well-reasoned approach to resolving social dimensions associated with scientific problems (*STL*)	2,7 (0,54)	3,5 (0,58)	- 3,59
Q16	Distinguish between structured, guided and open inquiry (*Inquiry-based learning*)	2,4 (0,64)	3,6 (0,50)	- 4,13
Q17	Guide students to put forward scientific questions and hypothesis for investigation. (*Inquiry-based learning*)	2,8 (0,50)	3,6 (0,57)	- 3,58
Q34	Encourage self-motivation by students in science lessons (*Motivation*)	2,7 (0,62)	3,6 (0,57)	- 3,85
Q37	Undertake a range of formative assessment strategies with one`s own students (*Assessment*)	2,1 (0,64)	3,6 (0,58)	- 4,28
Q40	I use Bloom's taxonomy in the preparation of test questions (*Assessment*)	2,7 (0,47)	3,5 (0,51)	- 3,79
Q41	I can use student study strategies which promote long term retention (*Theories of education*)	2,7 (0,60)	3,6 (0,58)	- 3,62
Q42	Give meaning to ZPD (Zone of proximal development) (*Theories of education*)	1,7 (0,72)	3,4 (0,69)	- 4,13
Q43	Aware of SDT and self-actualisation (Maslow`s hierarchy)) to motivate students (*Theories of education*)	1,8 (0,62)	3,4 (0,70)	- 4,31
Q44	Distinguish between intrinsic and extrinsic motivation of students (*Theories of education*)	2,3 (0,61)	3,4 (0,7)	- 3,87
Q46	Teaching in a constructivist manner so that students are guided to construct meaning of knowledge (*Theories of education*)	2,3 (0,73)	3,3 (0,72)	- 3,57
Q47	Make self-reflective teaching videotapes (*Self- reflection*)	2,0 (0,68)	3,1 (0,90)	- 3,61
Q48	Use of action research to make teaching more effective (*Self- reflection*)	1,9 (0,71)	3,5 (0,70)	- 4,26

COMPILING THE CPD PROGRAMME

The devised CPD programme was planned to begin by introducing the ;education through science; philosophy and interacting with exemplar modules Thereafter attention was paid to the 4 areas identified as major teacher needs, vis: Inquiry-based learning, Theories of education, Motivation and after trying out a module in the classroom, Reflection. Although Assessment was also a need, attention to this was planned later in the programme, after teacher had the opportunity to actually try out a few modules in the classroom situation. Interdisciplinary presentations were also distributed throughout the programme.

Table 7 An Overview of the planned CPD

Session	Topics covered	Mode of CPD	Time (hrs)
1.	**First day**		
	Philosophy/STL/NOS	Mode (1)	1,5
	Introduction to modules	Mode (7)	3,5 + 0,5 +
	Second day		0,5
	Inquiry-based learning (IBL)	Mode (2)	
	Interdisciplinary presentation (CK)	Mode (1)	1,5
	Theories of education	Mode (2)	2
	Introduction to modules	Mode (3)	1
			1,5
2.	**First day**		
	Motivation	Mode (8)	2
	Reflection on best practice	Mode (4)	1
	Introduction to new modules	Mode (2)	2
	Theories of education	Mode (9)	1
	Second day		
	Reflection on best practice	Modes (4) and	1 + 0,5
	Inquiry-based learning	(6)	1,5
	Introduction to new modules	Mode (1)	1,5
	Interdisciplinary lecture (CK)	Mode (3)	1,5
		Mode (1)	
3.	Reflection on best practice	Mode (4)	1
	Interdisciplinary lecture (CK)	Mode (1)	1
	Assessment	Mode (10)	2
	Modification of new modules	Mode (5)	2
4	Reflection on best practice	Modes (4) and	1 + 2
	Theories of education	(6)	1
	STL	Mode (1)	0,5
	Reflection on PROFILES in the	Mode (1)	1,5
	classroom	Mode (11)	

Key to Mode of CPD

Interactive Lecture; 2 – Interactive lecture + group work+ discussion; 3 - Power point slide presentation+ practical work + discussion in two groups; 4 - Discussion in groups + presentation to the whole group; 5 - Group work + presentations; 6 - Teacher power point presentations; 7 – role play and discussion in two groups + presentation to whole group; 8 – Interactive lecture with video + video analysis; 9 – Discussion in two groups; 10– Discussion in small groups + presentation + interactive lecture;; 11– SWOT analysis in small groups + presentation to whole group;

CPD Weighting

The planned CPD emphasis, in terms of percentage of time, was as follows (omitted a preliminary and post-interview discussion):

Introductions (approximately 30%); Reflection (approximately 25%); with the other topics - Inquiry-based learning. Assessment, Theories of Education, Motivation and Inter-disciplinarity - (approximately 6-9%).

Less time was allocated to STL as this was more familiar to the teachers and also planned to be incorporated into the introductions, while any references to Classroom environment was incorporated into Reflection and NOS/ Goals of Education into the introduction (teachers had earlier received CPD incorporating these aspects). (The sessions on Introduction/Modification to Modules were also planned to include components of Inquiry-based learning, Motivation, Theories of Education and Assessment).

CONCLUSION

All components in the teacher needs questionnaire were found to be appropriate for determining requirements for a CPD course identifying teacher needs (further indicated by teacher interviews).

Based on the research questions,

1. This study was able to develop and use a validation teacher needs questionnaire, composed of 52 items in 10 subscales, to determine teacher’s self-confidence levels and self-identified training needs for using education through science teaching modules in their science classrooms. The instrument was translated into Estonian and administered at a briefing session prior to the CPD. The findings from the questionnaire were collaborated and amplified by means of focus group interview with selected teachers.
2. The following subscales for the questionnaire were identified as topics to include in a 40 hours CPD programme

- Inquiry-based learning, assessment, theories of education and self-reflection, based on differences in self-confidence and training needs. Student motivation was also identified as a further topic which needed to be specifically identified in the CPD programme.

3. Emphasis in the CPD programme was clearly needed on the education through science philosophy and how this was operationalised in teaching modules. This was mainly identified by the self-confidence component of the questionnaire. Although teachers were able to distinguish between giving an indicator of self-confidence and the need for further training, the instrument was less suitable in separating emphasis for training needs – it seems the teachers were curious to see what training is offered in all aspects. In particular, emphasis was placed on teacher reflection after trying out modules in the classroom situation; interdisciplinary presentations on topics that straddled more that one of the subjects – biology, chemistry, geography, physics. Aspects such as assessment strategies, especially formative assessment; inquiry-based learning and educational theories were also heavily promoted particularly related to module development and student motivation.

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