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THE INFLUENCE OF AN INTERNATIONAL PROFESSIONAL DEVELOPMENT PROJECT FOR THE DESIGN OF ENGAGING SECONDARY SCIENCE TEACHING IN FINLAND

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INTRODUCTION

Students' declining interest and engagement in science learning and science-related careers has received significant attention in the international science education research community (Osborne & Dillon, 2008; Zeyer et al., 2013). The European Commission's Horizon 2020 Work Programme (EU, 2016) emphasises that school science should better represent real scientific practices and cater more effectively to the needs and interests of young people. *Inquiry-based science education* (IBSE) has been suggested as a solution to this problem of engaging students in science learning. However, there is not a common definition of IBSE and thus it has been characterised in a variety of ways. The active nature of student involvement through engaging them in scientific practices and collaboration is typically mentioned as characteristic of IBSE (Hake, 1998; Pintrich, 2003; Anderson, 2007; Minner, Levy & Century, 2010).

Due to the lack of students' engagement in science learning, the new Finnish framework curriculum emphasises the importance of student engagement in science learning (Finnish Ministry of Education and Culture [FMEC], 2013). Similar to the Next Generation Science Standard (NGSS) (National Research Council [NRC], 2012), the new Finnish framework curriculum suggests that students' engagement could be supported through focusing on the core scientific knowledge and practices and through students' active participation in project-based learning (PBL) that expands their knowledge acquisition. The scientific practices involve students in *asking questions and defining problems*; *planning and carrying out investigations*; *analysing and interpreting data*; *and developing explanations and designing solutions*. These movements in Finland and the U.S. are similar to movements in many other countries and are typically described as IBSE. We use PBL and scientific practices as a framework instead of IBSE, which we describe in detail later in this paper.

According to Minner, Levy and Century (2010), engagement in science learning is part of the definition of IBSE, as 'IBSE engages students…'. However, there are few research papers on engagement in the context of IBSE or which present evidence on how teachers could be guided to organise engaging science education. In one of the few papers focusing on engagement in the context of ISBE, Palmer (2000) argues that the novelty of the task, the possibility of choices and social involvement in learning correlate with student engagement. However, it was difficult to align engagement with a single component of the intervention. Therefore, Palmer calls for more research on students' engagement with specific components of instructional practices in the context of IBSE/PBL. There is thus no strong evidence regarding how engaging the use of scientific practices as a part of IBSE/PBL is for students or how teachers should be guided to employ these practices in their classrooms.

Although Finnish researchers and even teachers assume that IBSE could engage students in learning, teachers do not guide their students to engage in scientific practices (Lavoen & Laaksonen, 2009). In general, the research outcomes do not transfer to educational practices, in-service training or professional development programs (PDPs) (Radford, 1998; Russel & Martin, 2010). Teachers are not willing to learn new instructional practices that they do not immediately perceive as appropriate and interesting (Tobin, Tippins, & Gallard, 1994). Therefore, teachers should feel that the new instructional practices match their own habits and beliefs. It is a challenge to activate teachers in their own professional development; furthermore, the aims of the training should better meet the needs of the teachers (Borg, 2011).

This study presents results from collaboration between researchers and teachers in Finland and the U.S. As a part of this collaboration, science lessons which included scientific practices and project-based learning were designed together with researchers and secondary science teachers in both countries. These design activities are considered as a project aim to support teachers in their professional development (PD). These design activities, which we also refer to as the professional development project (PDP), had clear aims and included different kinds of interaction. Furthermore, the PDP was long term and consists of two cycles. As a part of this PDP, Finnish teachers observed lessons in the U.S. and participated in common international workshops. The teachers designed teaching modules in small collaborative groups and researchers visited these groups during the planning phase. An essential goal of the PDP was to help teachers increase students' engagement in their science classrooms through employing scientific practices as a part of PBL. Within the PDP, the teachers designed teaching modules. The research questions were as follows:

1. How did the designed teaching modules support students' engagement in learning?
2. What characteristics of the PDP supported Finnish teachers to plan engaging teaching modules?

Our principal goal is to evaluate the outcomes of the PDP through analysing the supportiveness of the teaching modules for student engagement. Therefore, our first aim is to determine the supportiveness of the teaching modules, with an emphasis on student collaboration and science practices for student engagement. If the modules are engaging, our second aim is to know more about the nature of PDP which supports teachers in designing engaging teaching modules.

IMPLEMENTATION OF RESEARCH OUTCOMES IN THE DESIGN OF THE TEACHING MODULES AND PDP

Due to the limited space, the review of relevant research on engagement, project-based learning and teachers' professional development are combined in the description of the design of teaching modules and PDP.

Engagement in the context of Flow theory

Much is known about interest, motivation and engagement, including their influence on learning. For example, task-based interest could be created by choosing an appropriate teaching method, grouping students, using an interesting activity, or offering students meaningful choices (Deci & Ryan, 2004). The role of context is emphasised as the starting point for the development of scientific ideas and interest (Bennett, Lubben, Hogarth & Campbell, 2004). Science-related engagement research emphasises the differences in male and female students' interest and the influence of the educational context on the development of such interest. Many researchers argue that in general, girls are less interested than boys in physics, and that student interest in physics decreases as student age increases (Tytler, Osborne, Williams, Tytler, & Cripps, 2008).

Many research outcomes considering student interest and motivation are based on survey or interview data. However, surveys and interviews have limitations because they obtain retrospective measures of students' reports on engagement experiences and their subjective feelings about them (Tuominen-Soini & Salmela-Aro, 2014). Although researchers agree that engagement is a changeable, malleable experience that occurs over time, existing studies pay limited attention to how students experience science learning situations (Fredricks & McColskey, 2012). Thus, measurements in real situations, like the experience sampling method (ESM) (Csikszentmihalyi & Schneider, 2000; Hektner, Schmidt & Csikszentmihalyi, 2007), could offer new insights on students' engagement in science learning and could reveal more about teachers' success in making science more engaging. Therefore, in contrast to those who have conceptualised engagement as a monolithic trend, we have specifically identified engagement as varying in intensity across different domains and situations, a characterisation that fits closely with current definitions of situational interest in science education research (Krapp & Prenzel, 2011). Moreover, engagement is not just an isolated and mechanistic phase in the beginning of the lesson that appeals to students' curiosity, but rather is built in the context of this research through employing PBL and scientific practices in various challenging and interesting learning situations.

We approach situational engagement in the context of flow theory (Csikszentmihalyi, 1990) through the following three pre-conditions: interest, skill, and challenge. In order to be engaged, a student should experience elevated levels of challenge in a task, but should also feel equipped with the requisite skills to undertake the task. Skill is defined as a mastery of a set of specific tasks, while challenge is defined as a desire to persist in a science learning situation (Eccles & Wigfield, 2002). A student must also experience situational interest in the task, as outlined by Hidi and Renninger (2006), Krapp and Prenzel (2011) and Lavonen, Juuti, Uitto, Meisalo and Byman (2005). Consequently, interest is defined as a psychological predisposition for a specific object. A student is considered to be engaged in a task when he or she simultaneously experiences elevated feelings of challenge, skill, and interest. Low levels of student engagement in science classes are a concern for both countries in the current study (OECD, 2007; OECD, 2013; President's Council of Advisors on Science and Technology [PCAST], 2012). Research has found that too many schools in the U.S. and Finland teach science superficially rather than encouraging integrated knowledge that allows students to draw upon their understanding to ask relevant questions, solve problems, make decisions, and learn new ideas (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014; Krajcik & Czerniak, 2013; Lavonen, 2013).

Project-Based Learning

Policymakers and researchers argue that pedagogical approaches which emphasise students' collaboration, problem solving and inquiry orientation support students' engagement and learning (Marx et al., 2004; Rivet & Krajcik, 2004; Williams & Linn, 2003). Such approaches could also prepare students for the twenty-first century better than traditional approaches (Trilling & Fadel, 2009; Binkley et al., 2012). In this research we have guided teachers to design teaching modules according to the PBL model, which was introduced by Krajcik and Shin (2015) (Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000).

The origin of this PBL is in learning sciences which aim to find ways to integrate knowledge that will allow students to draw upon their understanding to solve problems, make decisions, and learn new ideas. Learning sciences research has shown that students cannot learn disciplinary content without engaging actively in disciplinary practices; furthermore, they cannot learn these practices without learning the content through actively constructing their understandings by working with and using ideas in real-world contexts. In the context of science teaching and learning, Krajick and Merritt (2012) have emphasised the use of scientific reasoning, critical thinking and scientific practices, such as questioning, observing, inferring, classifying, predicting, measuring, interpreting and analysing, as a part of PBL. In so doing, students engage in scientific practices similar to those of professional scientists. Consequently, in order to form useable understanding, knowing and doing cannot be separated, but rather should be combined in problem solving, decision making, explaining real-world phenomena, and connecting new ideas and situations according to the theory of situated learning (Greeno, 2006; Lave & Wenger, 1991).

Learning sciences research also emphasises the important role of social interaction in learning. In practice, learners develop understandings of principles and ideas through sharing, using, and debating ideas with others (Blumenfeld et al., 1996). This process of sharing, using, and debating ideas back and forth helps to create a community of learners that supports students' ability to make connections between ideas.

Learning sciences research has demonstrated the important role of *cognitive tools*, such as graphs which help learners to see patterns in data. Digital tools could, as such, be considered cognitive tools because they allow learners to carry out tasks. For example, new forms of computer software allow learners to visualise complex data sets (Edelson & Reiser, 2006).

Krajcik and Shin (2015) suggest the following six key features of PBL in the context of science teaching (Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991; Krajcik & Czerniak, 2013):

- PBL starts with a *driving question*, i.e. a problem to be solved.
- PBLs focus on the learning goals of the curriculum/standards that students are required to master.
- Students explore the driving question through *participating in scientific practices*—processes of problem solving that are central to expert performance in the discipline. As students explore the driving question, they learn and apply important ideas in the discipline. They investigate questions, propose hypotheses and explanations, argue for their ideas, challenge the ideas of others, and try out new ideas.
- Students, teachers, and community members *engage in collaborative activities* to find solutions to the driving question. This mirrors the complex social situation of expert problem solving.

- While engaged in the scientific practices, *students are scaffolded* in order to help them participate in activities normally beyond their ability.
- Students *create a set of tangible products* that address the driving question. These are shared artefacts, i.e. publicly accessible external representations of the class's learning.

The characteristics of PBL are similar to IBSE. According to Anderson (2007), in a science inquiry, students in small groups typically begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. While engaging in inquiry, the students should understand that background knowledge and theories guide the design of investigations, the types of observations made, and the interpretations of data. In their review on research on IBSE, Minner, Levy and Century (2010) consider the characteristics of IBSE to include the following: its focus on life, earth, or physical science; the way it engages students with scientific phenomena and instructs them via some part of the investigation cycle (question, design, data, conclusion, communication); and its emphasis on student responsibility for learning or active thinking (p. 479). However, PBL emphasises the teacher's role in scaffolding and learning of concepts to a greater extent than IBSE.

Niemiec and Ryan (2009) argue that all humans would like to learn about their environment, and that learning should not be confused with external control. Therefore, scientific practices as a part of PBL have the potential to promote student engagement in science learning. While designing teaching modules during the PDP, the researchers and teachers aimed to design scientific practices as a part of PBL that were engaging for students. They also tried to ensure that students had an appropriate level of skill with respect to the task challenge. Consequently, the design of the teaching modules was based on the assumption that science learning in school should better represent real scientific practices and support collaboration in order to make it engaging (Andersson, 2007; EU, 2004; Tytler, 2014). Teachers designed teaching modules, for example, based on the following topics: 'The influence of strong and weak bonding on the chemical behaviour of substances'; 'Modelling different kinds of movements and use of these models in making predictions' and 'Predicting the behaviour of paper, plastic and metal based on the structure of matter'.

Teachers' professional development

Several researchers argue that PDP should follow the constructivist model or that it should be teacher-led, continuous (long term), situated in or connected to the classroom context, collaborative, and include reflective practices (Loughran, 2002; Lavonen, Juuti, Aksela, & Meisalo, 2006; Borg, 2011; Avalos, 2011; van den Bergh, Ros, & Beijaard, 2015).

Researchers have argued that individual and collaborative reflection on beliefs and/or experiences is essential for PDP (Bianchini & Colburn, 2000; Mansvelder-Longayroux, Beijaard, & Verloop, 2007). *Reflection* refers to a process in which beliefs and/or experiences are recalled, considered, and evaluated, usually in relation to a goal or larger purpose (Zimmerman, 2002; Rodgers, 2002). Collaboration during reflection helps teachers to share beliefs and/or experiences and enables them to learn from their experiences (Hiebert, Gallimore, & Stigler, 2002). Sowder (2007) argues that reflection and sharing of experiences with other teachers allows teachers to acquire new instructional practices, such as PBL. Therefore, reflection in a small group influences the learning of new instructional practices (Falk & Drayton, 2009; Linn, 2009; Yoon & Kim, 2010).

Oliveira (2010) states that many short-term PDP fail to foster teachers' deep understanding of instructional practices and their influence on students' learning and engagement. In a short PDP, teachers do not have enough time to reflect on and discuss their experiences of different instructional practices in different contexts.

We followed previous constructivist guidelines while planning the 2-year PDP in this study. Our first aim was to help teachers design teaching modules together with other teachers and researchers and to internalise the meaning of PBL and the role of scientific practices as a part of PBL. Our second aim was to support teachers to discuss and reflect on their experiences. One novel characteristic in the PDP was collaboration between teachers and researchers from two countries. Our assumption was that the teachers and researchers could learn from each other through collaboration, design of teaching modules and sharing of experiences.

The PDP consists of eight international contact meetings/workshops during a 2-year period, several teachers' co-planning sessions were organised and the Finnish researchers visit these planning sessions, as described below in Table 1. Two of the workshops were organised in the U.S. together with North American teachers. Within these workshops, the Finnish teachers followed PBL-oriented lessons in the U.S. schools. In three local workshops, the North American researchers participated as trainers. During this 2-year period, there were two implementations of the designed teaching modules and two data collection periods for gathering data on student engagement. Consequently, the PDP consisted of two cycles. The designed 2-week teaching modules aimed to support students' engagement in science learning through scientific practices as a part of PBL.

Table 1 *Contact Meetings (Workshops) During the PDP*

Year	Workshop	Topic of the workshop
2014	Three-day workshop, May 5–7 in the U.S.	- Three-dimensional learning (learning which combines scientific practices, core scientific concepts and disciplinary core ideas) - Modelling based on empirical data - Use of simulations for supporting the construction of a revised model
2015	Two-day workshop, January 19–20 in Finland	- Planning of a science investigation - Use of evidence when making a scientific argument - Modelling based on empirical data and improving models based on a new investigation
2015	Two-day workshop, January 26–27 in Finland	- Planning of teaching modules in small collaborative groups - Introduction of teaching modules and planning of revised models based on the feedback
2015	Intervention February (at school site of the participating school)	- A group of teachers planning the teaching modules at the school site - Researchers are visiting the school site
	Intervention and data collection	

2015	One-day workshop, May 20	- Discussion on the experiences of the data-collection process - Presenting of the engagement data from the classroom situations - Evaluation of the teaching modules and data-collection period
2015	Two-day workshop, December 8–9 in Finland	- Three-dimensional learning - Asking questions, use of evidence, modelling - Planning of teaching modules
2016	Two-day workshop, January 18–19 in Finland	- Project-based learning - Scientific practices and engagement - Planning of teaching modules
2016	Three-day workshop, February 6–9 in the U.S.	- Three-dimensional learning - Finnish and North American teachers planning the teaching modules together
2015	February (at school site)	- A group of teachers planning the teaching modules at the school site - Researchers are visiting the school site
	Intervention and data collection	
2016	One-day workshop, May 21	- Discussion on the experiences of the data-collection process - Presenting of the engagement data from the classroom situations - Evaluation of the teaching modules and data-collection period

METHOD

In order to evaluate the success of the PDP or how the engaging science teaching modules were designed collaboratively, the experience sampling method (ESM) was used to measure students' level of engagement in various science learning situations using the smartphone application during both cycles of the PDP (Csikszentmihalyi & Schneider, 2000) (See Table 2). The smartphones were installed with a special application that randomly signalled the students and indicated the time when they should respond to a series of questions (Hektner, Schmidt, & Csikszentmihalyi, 2007). We operationalised engagement as a state of involvement in a learning task identified by higher-than-average individual states of interest, skill, and challenge (Eccles & Wang, 2012; Reschly & Christenson, 2012). In the ESM questionnaire, 4-point Likert scale items were used to measure students' situational interest, skills, and challenges. Moreover, the students were asked to select the type of science practice and whether they were collaborating with other students when signalled. The ESM questionnaire is included in the appendix.

Table 2 *Data Collection During the PDP*

Year	Data collection period	Classes and subjects
2015	February 9–March 27/ April 13–May 29	Seven teachers and their respective classrooms were sampled during a 2-week period (two biology, one chemistry, and four physics teachers/classrooms). The students (*N* = 167) were in grades 9 through 12 and between the ages of 16 to 19.
2016	February 29–March 25/April 11–May 13	Nine (seven) teachers, who also participated in 2015, and classrooms were sampled during a 4-week period (five physics and four chemistry teachers/classrooms). The students (N = 193) were in grades 9 through 11 and between the ages of 15 to 17.

To validate the students' responses, we collected teachers' lesson plan data on each day that the students were surveyed. We also observed lessons to watch for the use of scientific practices in the classroom to verify the fidelity of the measurements and implementation. The teachers' plans generally matched the students' reports regarding their teachers' classroom practices. It is important to note that these results are not intended to be causal. The samples were selected for convenience and cannot be generalised to the larger population.

In order to evaluate how the teachers experienced the PDP and its support for the design of teaching modules, we asked teachers to evaluate the support of the PDP for planning the teaching modules through 5-point Likert scale questions and open questions. The teachers were asked to evaluate to what extent the characteristics of the PDP, such as 'Collaboration with Finnish teachers' or 'Situated, i.e. connection to practice', helped teachers in their planning of the teaching modules using the following scale: Not at all = 1; Very much = 5. An open-ended question asked teachers to evaluate the usefulness of the PDP (Table 4). In total, five of seven teachers answered the questionnaire.

The median for the Likert scale items was calculated in order to rank the characteristics of the PDP from the point of view of their usefulness. The open answers were analysed following the ideas of inductive content analysis (Elo & Kyngäs, 2008). The answers were read several times in order to ensure an accurate interpretation of the teachers' expressions and then answers were grouped into three themes.

RESULTS

The students' engagement measurements for the science learning situations during both cycles of the PDP are presented in Table 3. In each of the three data-collection periods, students' level of engagement in specific science situations was measured randomly.

Table 3 *Students' Engagement Measurements*

Year	Number of students	Number of engagement measurements	Percentage of students engaged in science learning situations in general	Percentage of students engaged in situations where scientific practices were employed	Percentage of students engaged in collaboration situations with other students
2015	167	1760	17.1%	21.0%	20.4%
2016	193	2686	23.8%	26.5%	22.4%

Table 4 presents the evaluations of how the Finnish teachers experienced the PDP, particularly in terms of how it supported the design of the teaching modules.

Table 4 *Finnish Teachers' Evaluations of the Extent to Which the Characteristics of the PDP Helped Them in Their Planning of the Teaching Modules*

Characteristics of the PDP	Median
Collaboration with Finnish teachers	5
Co-reflection with Finnish teachers	4.5
Collaboration with researchers	4.5
Planning of teaching modules	4.5
Following the North American teachers' lessons	4
Goal orientation (clear aims and structure of the PDP)	4
Situated, i.e. connection to practice	4
Lectures during the workshops	4
Collaboration with North American teachers	3.5
Ongoing and long-term nature of the PDP	3.5
Starting where teachers were in the beginning	3.5
Sharing the results (engagement data, experiences) of the efforts	3.5

According to the inductive content analysis of the answers to open questions, the teachers talked about their own personal professional development, especially the influence of the PDP on their competence to organise project-based learning and scientific practices. The teachers emphasised the positive influences of the PDP on their profession: '… [PDP] have given me great motivation to start using project-based learning and scientific practices and shown me how to put certain ideas into practice'. Another teacher shared, 'I'm still enthusiastic about this project and its aims'. The teachers sought the usefulness of the PDP for the implementation of the new curriculum, and especially the implementation of scientific practices in the classroom: ' … [PBL] orced students to think more about the connection between different variables and use physical quantities when explaining and reasoning in groups'. Another teacher said that it is 'interesting to see how the students developed their own models'. All teachers emphasised that they learned a new type of pedagogy which supports students' engagement and learning: 'I have excellent ideas now regarding how to work with students if I want them to develop and apply a deeper understanding'; '…most of the students enjoyed the new learning practices'; 'students learn to explain phenomenon based on the core ideas'. However, as the following excerpts illustrate, the teachers feel that they need more support from the researchers: '…some more feedback from the researchers was needed'; 'More ideas were needed regarding how to plan the teaching modules'.

DISCUSSION

The collected engagement data shows that teachers have been successful in planning teaching modules emphasising scientific practices in the context of PBL. In general, the randomly selected designed science learning situations were more engaging for students than the situations during the preliminary data-collection period (see also Schneider, Krajcik, Lavonen, Salmela-Aro, Broda, Spicer, Bruner, Moeller, Inkinen, Juuti, & Viljaranta, 2015). The situations when students employed scientific practices or were collaborating were especially engaging. Therefore, PBL promotes students' engagement in science learning. Collaboration as such is less engaging than scientific

practices. Our research proved that teachers could guide students in engaging scientific practices (Andersson, 2007; EU, 2004; Tytler, 2014).

Based on the three data-collection periods teachers have made progress in the renewal of their science teaching and have succeeded in making it more engaging for students. The teachers emphasised their progress in their open answers and described how the PDP supported them to organise project-based learning and scientific practices in a way which supports student engagement. The data on student engagement, which was randomly collected in classroom situations, show that designed collaborative learning situations and learning situations where students employ science practices engage students in science learning more than 'traditional' science learning.

Teachers evaluated that co-reflection and collaboration and planning of teaching modules with teachers and researchers had the greatest positive impact on their professional development and planning of the teaching modules. This is in line with other researchers who emphasise that reflection and sharing of experiences with other teachers support teachers in acquiring new instructional practices (Sowder, 2007; Falk & Drayton, 2009; Linn, 2009; Yoon & Kim, 2010). In fact, all characteristics of the PDP were evaluated as positive for the teachers' professional development. For example, goal orientation and the long-term nature of the PDP fostered teachers' deep understanding of instructional practices and their influence on students' learning and engagement (Oliveira, 2010). The importance of goal orientation and the long-term nature of the PDP were also recognised in the engagement data (Table 3). The percentage of engaging situations increased between the first and second cycle.

We believe that our international collaboration in organising a constructivistic PDP which supported teachers to design and implement engaging project-based learning was successful. The PDP included two cycles and teachers were guided in collaboration and reflection. Reflection was supported by situational engagement measurement.

Some of the benefits of international collaboration between researchers and teachers in Finland and the U.S. have yet to be realised. Even though the Finnish teachers were guided to engage in collaboration during the international workshops, the teachers did not report the benefit of this characteristic of the PDP in the Likert scale and open questions. Therefore, there is a challenge to develop this international partnership during the third cycle of the project. For example, new types of Internet-based approaches for monitoring and following up on lessons are needed.

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Appendix – Student ESM Questionnaire

1. What were you doing when signalled?
    - Listening
    - Discussing
    - Writing
    - Calculating

- Taking a quiz/test
- Working on a computer/technology
- Working in a group
- Working in a lab
- Presenting
- Other

2. Which best describes what you were doing in science when signalled?

- Asking questions
- Developing a model
- Using a model
- Planning an investigation
- Conducting an investigation
- Analysing data
- Solving math problems
- Constructing an explanation
- Using evidence to make an argument
- Evaluating information
- Other

3. Who were you with?

- Teacher
- Classmates
- Teacher and classmates
- Friends
- Other students
- Relatives
- Alone
- Other

4. How did you feel about the main activity (4-point scale: 1 = Not at all/ 4 = Very much)

a.	Were you interested in what you were doing?	1	2	3	4
b.	Did you feel skilled at what you were doing?	1	2	3	4
c.	Did you feel challenged by what you were doing?	1	2	3	4

ROLE OF CONTEXTUAL KNOWLEDGE IN THE PEDAGOGICAL CONTENT KNOWLEDGE OF GRADE 9 NATURAL SCIENCES TEACHERS IN JOHANNESBURG

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1. INTRODUCTION

This study explores the role of contextual knowledge in the pedagogical content knowledge of selected Grade 9 Natural Sciences teachers in Johannesburg. It is part of a larger study which involved teachers in professional development on what constitutes contextual knowledge and how to incorporate this contextual knowledge in science teaching. The study then explored the teachers' knowledge of learners' socio-cultural background herein referred to as contextual knowledge, investigated how teachers can incorporate contextual knowledge in order to make science concepts more comprehensible to the learners and also sought teachers' reflections of how contextual knowledge influences their knowledge domains such as subject matter knowledge, pedagogical knowledge, orientations to science teaching and overall their pedagogical content knowledge.

1.1 IMPORTANCE OF TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE IN SCIENCE TEACHING

Previous research has shown that pedagogical content knowledge (PCK) is essential for effective teaching (Abell, 2007; Loughran et al., 2012). Shulman and Sykes (1986) described well-developed PCK as the teacher's ability to determine aspects of particular topics that are most difficult for learners to understand. A number of researchers have shown that PCK plays a vital role in the planning of the subject matter to be taught and learnt (Clermont et al, 1993; Van Driel et al, 1998). PCK also shapes the teachers' acquisition of new instructional approaches and strategies (Borko & Putnam, 1996) and in the process influences the learning process (Carpenter et al, 1988). Because PCK is subject and topic specific, teachers develop appropriate knowledge to teach content in a particular way (Hashweh, 2005). Therefore PCK enables teachers to understand alternative ways of representing knowledge so that it becomes more comprehensible to the learners (Botha & Reddy, 2011). As a result, the teacher would identify analogies, metaphors, examples, similes, demonstrations, simulations, manipulations (Shulman, 1986) and the most effective communication strategies suitable for learners of particular background to understand.