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Enhancing untrained science teachers' pedagogical content knowledge (PCK) in developing countries through teachers' professional learning communities (PLCs)

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Abstract

This paper reports on the findings of a study that can inform new approaches to solving the worldwide problem of teachers in current practice who are unqualified and/or underprepared for classroom teaching. The study approached the problem by focusing on ways to strengthen the pedagogical content knowledge (PCK) of unqualified licensed science teachers in the Tanzanian context. The findings indicated that the intervention strengthened generic aspects of the licensed science teachers' PCK for inquiry learning, notably their increased use of learner-centred pedagogical practices, with the potential for roll out to the wider educational community.

Keywords: Learner-centred; Licensed science teachers; PCK; Professional development; PLCs

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1. Introduction

This paper reports on a professional development intervention (PDI) for teachers, designed and implemented in response to an emerging global issue that is impacting negatively on teaching quality and threatens the achievement of reform-based societal goals through education especially in developing countries (United Nations Education Scientific and Cultural Organization, 2007). The issue is the inadequate supply of qualified teachers internationally, even across first world countries. This global shortage of teachers stems largely from rapidly growing school sectors in emerging countries which is being aggravated by a number of other factors too, including the aging teaching population, the high turnover rate of teaching staff, and the unattractiveness of teaching as a career compared to other careers (Ingersoll, 2002; Santiago, 2002).For example, the problem of teacher shortages is reported in USA urban schools, particularly in areas such as special education, mathematics and science (U.S. Department of Education, 2004). However, the problem is most acute in developing countries. The recent expansion of the elementary and secondary education systems in these countries is exacerbating the shortages of qualified teachers (Fyfe, 2007; Ingersoll, 1999), especially in Southern Asia and much of Africa (Audrey-marie and DeStefano, 2008; Millward, 2006). In its growing education sector Sub-Saharan Africa alone needs almost four million new teachers to fill the available school positions by 2015 (Millward, 2006; Saroj, 2009). To address this shortfall of teachers, governments in different countries have responded by adopting both long-term and short-term strategies. Commonly used strategies include: provision of alternative routes of entry into the teaching profession or the licensing of under-qualified/unqualified candidates; improving working conditions to attract qualified teachers who have retired from teaching; and distance learning approaches (Conner, 2009; Even and Leslau, 2010).

Of these options, the alternative route of entry/licensing under-qualified candidates into the teaching profession has proved to be the most popular and widely used short-term strategy in both developing and developed countries for increasing teacher numbers (Dahlkemper, 2002; Lynd, 2005; Mitchell and Romero, 2010; Teaching Australia, 2007). However, these alternative routes to teacher recruitment can have inherent dangers for the future quality of teaching and the learning of their students because the quality and duration of induction courses vary from one country to another. In some of the developed countries like the USA, New Zealand, and the United Kingdom, alternative route teachers are trained through university tailored educational courses or papers (Legler, 2002) that "…typically involve some period of intensive, condensed academic course work or training. [and] ...usually require a period of supervised, on-the-job training in which new teachers are expected to learn their teaching skills in the classroom" (p. 4). Thus alternative routes usually (but not always) refer to the recruitment of university graduates who are then licensed or certified to teach in schools without being trained in an accredited teacher education (long-term) programme (Heine, 2006; Legler, 2002). Unfortunately, it is common in developing countries for many alternative route teachers not to have a bachelor's degree, only having completed secondary schooling and short induction courses before beginning as classroom teachers. In Tanzania, these alternative route teachers are referred to as 'licensed teachers', 'crash programme teachers' or 'vodafaster teachers (Lynd, 2005; O-saki, 2007). As 16-18 year old school leavers, they frequently only possess pass grades in their secondary qualifications, and receive just four weeks of induction training before being placed in teaching positions at government secondary schools. Across other African countries the length of similar training varies widely: in Niger and Mali such teachers receive nine weeks; in Senegal and Mauritania twelve weeks; and in Burkina Faso one year (Duthilleul, 2005; Fyfe, 2007; Saroj, 2009). These licensed teachers' lack of tertiary qualifications in their subject domains, like mathematics and science for example, combined with minimal pre-service teacher education strongly suggests that their professional knowledge is underdeveloped and the learning success of their students is potentially at risk. To date, little attention has been paid to the potential knowledge gap of these unqualified teachers and their impact on sustainable global education by the international community. This study set out to investigate the reality of classroom life for such teachers and their students in the context of Tanzania, which resulted in the development of a professional development intervention (PDI) tailor-made for meeting the professional learning needs of the teachers. The PDI model developed in this study has the potential for adaptation to other educational contexts with similar issues.

The first phase of this current study, which investigated and identified the PCK needs of six licensed science teachers from Tanzanian secondary schools confirmed fears about the negative impact of using licensed science teachers and showed that Tanzanian students' quality of learning is falling dramatically (Anney et al., 2012). Following other Tanzanian studies concerned about decreasing levels of teaching efficacy and student achievement (Ministry of Education and Vocational Training, 2012), this study initially compared students' science and mathematics examination results from four Tanzanian National Government secondary schools employing qualified science teachers with those of students from four Tanzanian Government Community secondary schools being taught by unqualified licensed science teachers. The results showed that students in National Government schools with qualified teachers showed significantly higher performance in the science and mathematics examinations compared to Community Government secondary schools with unqualified teachers. The findings also revealed that the professional knowledge of the licensed science teachers participating in the study was generally underdeveloped for student-centred teaching and inquiry learning in science. For example, the licensed science teachers had:

- the belief that effective science teaching needed teaching and learning resources, and their own classroom teaching practices were being negatively influenced because of this lack of such resources rather than their lack of professional knowledge and experience;
- limited knowledge of their science content and curriculum;
- under developed knowledge of instructional strategies, particularly learner centred teaching approaches;
- limited knowledge of learners and their characteristics; and
- limited understanding of knowledge of student assessment strategies;

The finding that the licensed science teachers rarely used learner-centred teaching methods in their classrooms was particularly significant given its importance to the pedagogical content knowledge (PCK) needed for effective learning (Anney, 2013; Anney et al., 2012), and the declining trend in student science achievement at the rural secondary schools in the study. This decline was subsequently linked by the researchers to the weak PCK of the licensed science teachers in the secondary schools (Anneyet al., 2012) and it was evident there was a clear need to support these licensed teachers in enhancing their PCK for teaching science.

With this appreciation of the licensed science teachers' learning needs in the study, the Tanzanian researcher (first author) began work on designing a purpose-built PDI to strengthen their PCK. Since the recently adopted Tanzanian science education curriculum explicitly advocates the use of constructivism theory and learner-centred instruction in both primary and secondary education (Ministry of Education and Vocational Training, 2007), the researcher spent approximately three months as part of the lead up to the study observing and participating in pre-service science teacher education programmes promoting inquiry and learner-centred pedagogies at a New Zealand (NZ) University. A decision was made to design and implement a PDI that identified and addressed the licensed science teachers' specific PCK needs in such a way that they 'owned' the intervention and could learn collaboratively with their colleagues in the context of school-based PLCs within their Tanzanian communities. Such an approach was thought necessary because the researcher hypothesized the context of authentic practice would enhance the chances of success. The research questions guided this study:

- How effective was the implemented PDI in meeting licensed teachers' professional learning needs, in particular those related to PCK?
- How did students' classroom experiences and learning reflect teachers' PCK development after the PDI?

The next section details the rationale underpinning the nature of the intervention including current understandings of PCK and means of PCK development from the literature.

1.1. Pedagogical Content Knowledge (PCK) development

PCK is considered a unique category of professional knowledge for teachers (Rollnick et al., 2008). It was introduced by Shulman (1987) as the professional knowledge experienced teachers possess "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (p. 9) and differentiates teachers from subject specialists. PCK is "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 7). Practicing classroom teachers use this specialized form of professional knowledge in organizing, managing, elaborating, demonstrating and presenting the subject matter more comprehensively to learners (Lederman and Gess-Newsome, 1992). Since the Shulman publication, many other attributes of PCK have emerged and its components have been expanded upon (Loughran, Berry, andMulhall, 2006; Magnusson, Krajcik, and Borko, 1999; van Driel, Verloop, and de Vos, 1998). For example, Magnusson et al. (1999) proposed five components of PCK for science teaching: orientation towards science teaching; and knowledge and beliefs about science curriculum; assessment in science; students' understanding of science; and instructional strategies for science teaching.

Although many educational researchers might perceive PCK differently, it is an accepted and useful academic construct in teacher education, since a teacher's ability to transform subject content knowledge into understandable student learning outcomes and to use appropriate instructional strategies can be linked to the level of their PCK development (Vavrus et al., 2011). Thus the emphasis in teacher education is not only on promoting understanding of this form of professional knowledge but also on finding ways to develop and/or generate teachers' PCK (Schneider and Plasman, 2011). Research into how PCK is built by van Driel et al. (1998) revealed "teaching experience as the major source of PCK, whereas adequate subject-matter knowledge appears to be a prerequisite" (p. 673). Thus mastery of the content for teaching is a fundamental requirement for PCK development but a teacher's PCK can only evolve and become more sophisticated after many years of experience in teaching (Hume, 2010). A useful framework for identifying key sources of teachers' PCK development throughout their careers was outlined by Howey and Grossman (1989). These sources include: first, specific subject content knowledge training such as physics, biology and chemistry; secondly, internship experience by teacher trainees teaching particular subjects; thirdly, teachers' education training in courses related to subject-specific components such as instructional methods, curriculum, and psychology; and, finally, attending specific courses or workshops as part of on-going professional development.

The manner in which PCK develops over time and experience means that PCK is typically personal and idiosyncratic, topic specific and situational (van Driel and Berry, 2012). It also tends to be tacit since teachers have few opportunities to share it with colleagues. Thus, to novice teachers PCK can be rather elusive in nature and knowing exactly what it comprises during lesson preparation and teaching is a difficult task for them (Kind, 2009). Recently, moves by Loughran et al. (2006)to make experienced teachers' PCK explicit via exemplars, in the form of resource portfolios containing Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs), have been very helpful in initiating discussion around PCK and what it looks like in practice. Follow up studies have described how pre-service science teachers trained through Content Representation (CoRe) design are able to develop the foundations for a tentative form of PCK (Hume, 2010; Hume and Berry2011, 2013), while Nezvalová (2011) found that pre-service teachers taught using an action research approach also acquired some basics of PCK, in particular, knowledge of students' conceptions, understanding students learning difficulties and instructional strategies.

In reform-based education teachers who demonstrate the use of learner-centred instructional strategies effectively in their classrooms settings are found also to have a well-developed PCK because "student learning depends to a large extent on teachers' ability to transform their subjects into lessons that their students can comprehend" (Vavrus et al., 2011, p. 75). According to du Plessis and Muzaffar (2010) and Thompson, Licklider, and Jungst (2003) teachers using learner-centred education:

- provide the necessary support for students to develop inquiring minds;
- value student prior knowledge and experiences and integrate these experiences in the teaching and learning process;
- provide opportunities for students to learn new concepts and processes from peers through interaction using concrete examples and students' own reflections;
- provide opportunities for learners to express their own thoughts as a way of enhancing their understanding; and
- provide safe environment that support learning, correctness of answers is arrived through dialogue and debate and not through authority of a teacher.

It would appear these dispositions towards student-centred pedagogy underpin well-developed PCK (du Plessis and Muzaffar, 2010; Gardner and Gess-Newsome, 2011; Meece, 2003; Park, Jang, Chen, and Jung, 2011). As argued elsewhere in this paper PCK is complex, topic specific, bound to specific classroom contexts and learners, and exists in a form that is difficult to pin down exactly what actually it look like which also makes it difficult to generalise (Hume, 2010; Rusznyak and Walton, 2011). In linking PCK with learner-centred education practices this paper attempts to conceptualise PCK "as a collection of teacher professional constructions, as a form of knowledge that preserves the planning and wisdom of practice that the teacher acquires when repeatedly teaching a certain topic" (Hashweh, 2005, p. 290), while at the same time drawing out some of its more generic aspects to inform teachers' professional learning.

1.2. Pedagogical Content Knowledge as a knowledge continuum

Various studies have indicated that a teacher's PCK can be portrayed in terms of its position on a continuum with weak underdeveloped PCK components at one end and rich strongly developed PCK components PCK at the other (Gardner and Gess-Newsome, 2011; Y.-C. Lee, 2011; Penso, 2002). In taking the stance that PCK has a continuum nature some studies (e.g. Gardner and Gess-Newsome, 2011; Lee et al., 2007; Park et al., 2011) have developed rubrics in order to measure teachers' PCK. Taken collectively these PCK rubrics would indicate that teacher with weak PCK for teaching inquiry learning in science typically:

- lack adequate skills to focus on the main science ideas in a given topic;
- depend heavily on textbooks and teachers' guides as their main teaching resource;
- teach more factual science knowledge instead of enhancing student understanding of scientific concepts;
- do not acknowledge students' prior knowledge in their teaching with limited understanding of students' learning difficulties, weak diagnostic strategies for evaluating students' learning difficulties, preconceptions and misconceptions and little attempt at addressing students' learning difficulties in their lesson plans;
- employ non-interactive teaching methods with lesson plans that habitually use one teaching instruction approach and little or limited consideration of variations in students' learning approaches;
- begin a lesson with verification of the previous lesson content and direction to students about how to study in the new lesson but without the essentials features of inquiry-based teaching; and,
- use representations such as examples, illustrations, models and analogies that are ineffective, irrelevant and scientifically inaccurate or not linked to students' prior experiences (Gardner and Gess-Newsome, 2011; Jüttner et al., 2013; Lee et al., 2007; Loucks-Horsley and Matsumoto, 1999; Park et al., 2011; Penso, 2002)

On the other hand teachers with strong PCK for inquiry-based learning in science typically:

- draw up their lesson plan and content based upon students' prior knowledge;
- acknowledge variations in students' approaches to learning and provide diverse opportunities for students' to engage their own learning strategies;
- consider students' learning difficulties as a core aspect of their lesson planning and address them during the lesson;

- adopt all essential features of authentic scientific inquiry in students' learning such as engaging learners in scientific oriented questions, and requiring learners to provide evidence in responding to questions; and
- use representations that are pedagogically effective, scientifically accurate and connected to students' prior knowledge (Gardner and Gess-Newsome, 2011; Lee et al., 2007; National Research Council, 2000; Park et al., 2011).

This continuum model of PCK implies a teacher's PCK can be enhanced and research points to teachers' participation in professional development, reflective practice, and access and use of high quality learning materials as means by which this enhancement can be achieved (Gess-Newsome et al., 2011; Lee, 2011). It also provides a means by which enhancement of a teachers' PCK can be determined.

1.3. Reform-focused professional development

Turning the focus to in-service teacher education (commonly termed professional development) van Driel and Berry (2012) advocate the enhancement of teachers' PCK as an important goal of professional development programmes, and there is much evidence in the literature suggesting that teacher's participation in programmes with this goal helps to improve their PCK development (du Plessis and Muzaffar, 2010; Loucks-Horsley and Matsumoto, 1999). To involve teachers in more purposeful and active learning with greater likelihood of long term professional growth and benefits for classroom teaching and learning, many teacher professional development programmes are taking a new approach to teacher education encapsulated by the term 'professional learning' (Darling-Hammond et al., 2009; Ferrier-Kerr et al., 2008). In this approach professional learning is "a product of both externally-provided and job-embedded activities that increase teachers' knowledge and change their instructional practice in ways that support student learning" (Darling-Hammond et al., 2009, p. 1). Perhaps more importantly for this study it is also viewed as an internal process through which individuals acquire professional knowledge and skills and change their orientations towards teaching in order to improve student learning (Timperley et al., 2008). Timperley et al. (2008) argue that "without professional learning, professional development is unlikely to have any impact, so any well-constructed professional development experience should be designed to promote [teacher] learning" (p. 3). To support teachers' professional learning there is now an emphasis in professional development on collaborative models based within and around schools (Ferrier-Kerr et al., 2008), where attention is switching to professional learning communities (PLCs) for the achievement of meaningful, long-term teacher learning. Teachers' PLCs are considered a vehicle for reforming science education because when teachers work together in this way their classroom practice is positively impacted (Jones et al., 2013). Several studies have identified inherent characteristics or tenets that make these PLCs successful at promoting teacher change and positive student learning outcomes. These tenets include: shared values and vision about teaching amongst members of the PLC (DuFour and DuFour, 2006; Ferrier-Kerr et al., 2008); teachers' collective responsibility and mutual accountability in relation to changing classroom practices (Fraser, 2005; Vescio et al., 2008); collaboration among members of the PLC that promotes changes in the teaching culture by participating openly in discussions to encourage sharing of knowledge (Cormier and

Olivier, 2009; Feger and Arruda, 2008); the presence of reflective dialogue among members of the PLC on teaching and learning issues (Ferrier-Kerr et al., 2008); de-privatizing of the practice of teaching by teachers through sharing of personal classroom practice and experiences (Cormier and Olivier, 2009; Vescio et al., 2008); and a supportive environment where the leadership share responsibilities within the community of practice (Feger and Arruda, 2008).

2. Methodology

This present study was conducted in two contexts: New Zealand and Tanzania. The Tanzanian researcher was mentored by the NZ science education lecturer (second author) in various pedagogies for enhancing pre-service teachers' PCK for student-centred inquiry learning using constructivist and sociocultural views of teaching and learning. This mentoring helped the researcher to gain further understanding in this field, which he began relating to the Tanzanian context. Mindful of cultural and other contextual differences between the NZ and Tanzanian educational contexts, the researcher gathered and later adopted and/or adapted resources, ideas, and strategies from the NZ science education programmes that he thought were relevant and appropriate in the Tanzanian context for enhancing the licensed science teachers' PCK. Armed with new insights from his New Zealand experiences about the professional learning the licensed science teachers in his study needed to achieve to enhance their PCK, the researcher returned to Tanzania and developed an initial draft of a PDI to share with his teachers.

- ***Workshop one***

Two modules were studied during the first workshop session. The first module was intended to help the licensed science teachers gain an understanding of working together as a learning community of teachers. The researcher believed that understanding the tenets of PLCs was likely to help them develop a culture of working together through sharing the skills they had gained and supporting each other in teaching challenging science content. The second module introduced the licensed science teachers to the basics of lesson preparation, such as: writing objectives using action verbs; the selection of teaching and learning materials; assessment strategies; writing classroom level lesson 'competencies'; and evaluating the lesson. Lesson competency/competencies is a recently introduced concept in the Tanzanian science education curriculum, defined as 'a general statement detailing the desired knowledge, [behaviour] and skills it is intended students achieve by the end of the instruction session or course programme' (Hartel and Foegeding, 2004). The licensed teachers were also given the opportunity to evaluate different lesson plan templates from their schools and their old lesson plans in relation to the key features of well stated lesson objectives and students' lesson competencies.

- ***Workshop two.***

The second workshop covered modules three and four. Module three introduced the licensed science teachers to the broader concept of learner-centred education which was considered relevant to the licensed science teachers because the Tanzanian science education curriculum advocates the use of strategies in classroom teaching. Module four focused on gaining understanding of different conceptions of teaching science to help the licensed teachers make informed decisions when choosing relevant teaching method(s) for a particular science topic. They were encouraged to critically examine various teaching concepts such as: teaching as transmission, interaction or transformation; imparting of knowledge; facilitating of knowledge; and conceptual /intellectual change.

- ***Workshop three.***

This workshop covered modules five and six. Module five introduced the licensed science teachers to the importance and purpose of reflecting on their teaching practices and to the keeping of reflective journals for evaluating their classroom teaching practices. Reflection was considered crucial for the licensed science teachers to help them interpret their teaching experiences, to re-evaluate their classroom teaching practices for the purpose of improving their next lesson so that students' learning can also be improved, and to develop new understanding about classroom teaching (Titus and Gremler, 2010). Module six exposed the licensed science teachers to the ideas of Lee Shuman (1986, 1987) concerning the knowledge base of teachers and the categories of knowledge that comprise this base. This module explored the major sources of knowledge for teaching and the use of pedagogical reasoning and action to teach science and generate new understandings of teaching science. Teachers' understanding of the different categories of teaching knowledge was considered important because it helps to broaden their understanding of the teaching profession.

- ***Workshop 4.***

This workshop covered modules seven and eight. Module seven explored the use of formative and summative assessment in learner-centred education focusing on how to use different leaner-centred strategies for assessing students' learning during teaching i.e., assessment for learning. Module eight encompassed teaching portfolios and how to use them as assessment tools for science teachers. The licensed teachers also explored strategies for organizing a science portfolio and the nature of the content.

2.1. Participant recruitment

Purposive sampling technique was adopted in this study to select participants because it helped the researcher to focus on key informants who were particularly knowledgeable about the issues under investigation (Schutt, 2006), and it also allowed judgmental decisions about participants selection to be made (Ary et al., 2010; Bernard, 2000). Four community secondary schools were selected in the Manyara Region (United Republic of Tanzania) as case study schools, based on criteria such as their students' under-achievement in science subjects, shortages of qualified teachers and dependence on the recruitment of unqualified licensed science teachers to staff their schools, and their close proximity to facilitate contact and collaboration between teachers. From these schools, the researcher then purposively selected a unique group of unqualified licensed science teachers. Since participation in this study was voluntary, only those licensed science teachers who accepted an initial invitation were involved in this study. The researcher assumed that licensed science teachers would have experiences to share in the due course of this study because they had been working as untrained or unqualified teacher recruited through the alternative route approach.

A total of six untrained licensed teachers from the four community secondary schools and 24 of their students volunteered as participants in the study. The six licensed science teachers all held a high school secondary education certificate, but none had completed a university degree. However, three of them had attended a one-month teaching induction course and were enrolled at the Open University of Tanzania while another had begun a geology degree at the University of Dar Es Salaam but his studies had lapsed. The remaining two teachers were fresh from high school with no other training. At the time of the study Manimo and Pombe (pseudonyms) were third year students at the Open University of Tanzania and had worked five years in schools as licensed science teachers, while Tiita (pseudonym) was in his second year at the Open University of Tanzania student with four years teaching experience. Sungura (pseudonym) had completed three years of teaching but Safari and Qwary (pseudonyms) had only been teaching one year as licensed science teachers immediately after their own secondary schooling. The twenty four students comprised 12 girls and 12 boys aged between 14-16 years: four grade 9 students from Hewasi secondary school, four grade 9 students from Tlawi secondary school, eight grade 7 students from Nungu secondary school, and eight grade 8 students from Katani secondary school (school names are pseudonyms). At the end of lessons the researcher invited students to volunteer for focus group discussions.

2.2. Research design

This study adopted a case study approach within an interpretive research methodology using qualitative data collecting methods to explore the research problem (Yin, 2009). Qualitative research methods are usually considered when the research aims to investigate a complex social problem that is difficult to be studied quantitatively, and where the researcher wants to generate the data necessary for understanding the social problem comprehensively (Curry et al., 2009). As Denzin and Lincoln (1994) commented, qualitative researchers "study things in their natural settings, attempting to make sense out of, or interpret phenomena in terms of the meaning people bring to them...it involves collection of variety of empirical materials—case study, personal experiences..." (p. 2). A qualitative methods approach was also considered suitable for because it allows the researcher to focus on one idea to be explored or understood, and it can use a single case or a few participants (Creswell, 2009; Kaplan and Maxwell, 2005). In this study the researcher was able to interview school headmasters and district education officers, ward education officer and regional school inspector for the purpose of triangulating teachers' views in order to collect richer information about teachers' classroom teaching practices.

2.3. Theoretical framework

This study adopted 'situativity theory' as a theoretical framework for informing the design of the teachers' PDI because it assumes that teachers' knowing and learning are situational and influenced by social engagement in a professional learning community of teachers (Pella, 2011; Putnam and Borko, 2000; Richardson, 2003). According to Durning and Artino (2011) situativity theory is an advanced extension of constructivist and socio-cultural theories of learning since it "emphasizes learning as being connected to the situation, with individual cognition and meaning being socially and culturally constructed" (Owen, 2004, p. 4). A number of studies have indicated that situativity theory is a powerful lens for studying teachers' professional learning (Borko and Koellner, 2008; Owen, 2004; Pella, 2011), because it values school-based teacher learning and provide teachers with opportunities to practice and share their new learned skills

(Duncombe and Armour, 2004). School-based teacher learning supports the major assumption of situativity theory because it develops teachers coleagility (Horn, 2009). The professional development training in this study was sequenced to allow teachers to practice new skills learned in the first workshop session in school context with other teachers and to come up with new ideas of what worked and what should be improved to inform the next workshop session. This iterative process means that teachers construct their own knowledge through social engagement via collegial interaction (Horn, 2009; Lave and Wenger, 1991), and this construction of knowledge is the result of active participation in social discourse as a community of practice (Greeno, 1997; Henze et al., 2009). Teachers' "collegial conversations support the development of PCK and highlights professional learning through the discourse of collaborative teacher communities" (Horn, 2009, p. 1451), because effective professional learning requires a theoretical framework that consider learners in their workplace and social settings.

2.4. Data collection and analysis

This study employed focus group discussions, teachers' reflective notes and classroom observations as data collection methods. A systematic sequence of data collection occurred over an extended period that included: gathering of licensed teachers' written reflection notes from each workshop (see Appendix 2 for reflection guide); a focus group discussion with the licensed science teachers shortly after the PDI was completed (see Appendix 3 for interview question schedule); and classroom observations by the researcher eight months after the PDI to determine the nature and extent of any change in teachers practice. All observed lessons were video-recorded by the researcher from which classroom episodes of the teachers' classroom practices were summarized according to the themes of the study. The researcher used the videoed lessons to extract summaries of teachers practice before and after to detect PCK growth using PCK rubrics (see Table 1) and to quantify the number of questions asked before and after PDI to see if there was change in the teachers practice (see Table 2). Four focus group discussions were conducted with 24 students eight months after the PDI (see Appendix 4 for interview question schedule); and the licensed science teachers responses to evaluative questions were also collected eight months after the intervention (see Appendix 5 for reflection question schedule). The focus group discussions with students focused on the use of a learner-centred teaching approach, which is popularly known by Tanzanian students as the 'participatory teaching method' (famously known as *njiashirikishi* in Swahili local language). Since this study was very concerned with understanding teachers' and students views about the impact the PDI had on the teachers' classroom practices and enhancement of their PCK, thematic analysis of the data using both deductive and inductive approaches (Buetow, 2010; Guest et al., 2010) was used. The inductive approach is data-driven drawing themes from the data (Boyatzis, 1998; Guest and McLellan, 2003), while the deductive approach (Fade and Swift, 2011; Fereday and Muir-Cochrane, 2006) draws themes from an existing theoretical framework – in this study the PCK framework of Magnusson et al. (1999) and indicators of student-centered instruction derived from the literature were used to examine and identify the licensed teachers' PCK needs and enhancement around inquiry-based learning in science. The researcher also employed a *stepwise replication* qualitative strategy to analyze data where the first researcher analyzed the data, and another qualitative researcher analyzed the same data separately.

Table 1. Licenced science teachers classroom practices before and after PDI

Name of teacher	Summary of classroom practices before PDI	Summary classroom practices after PDI
Manimo	• Teacher started the lesson without revising previous lesson • Objectives of the lesson were not stated to students in advance and teacher did not have lesson plan • Teacher was directly copying student notes from the books • Teacher solved all examples himself on the blackboard without involving students • Teacher used whole classroom interaction approach like "are together? Or have you understood?" • Lesson was not summarized or evaluated and teacher did not provide students with homework	• Before start of new lesson teacher revised previous lesson and linked it with new lesson • Students were arranged in groups to discuss the lesson concepts and teachers provided extra explanation • Students were given opportunity to solve question on the blackboard • Teacher asked 13 formative questions • Students' learning was evaluated and lesson summary was written on the blackboard
Qwary	• Teacher started the lesson by revising the previous lesson • Objectives of the lesson were not explained in advance to the class • While teaching teacher talks to the blackboard and not to students • Teacher did not have lesson plan and he was using a book as his teaching notes • Teacher answered all the questions he asked his students himself • Lesson was not summarized or evaluated	• Teacher started the lesson by revising the previous lesson and appointing students to solve some of their homework on the blackboard • Objectives of the lesson were outlined on the blackboard • Teacher had a lesson plan and lesson notes • Students worked in groups during the lesson • Lesson was summarized and evaluated • Teacher asked 19 formative assessment questions during two lesson observed
Tiita	• Teacher started the lesson by revising the previous lesson • No teaching aids were used to support teaching and student learning • Lesson objectives were not identified in advance • Teacher used whole classroom instruction approach • Lesson was not evaluated and he did not give homework for students	• Teacher started the lesson by revising previous lesson and checking a few student exercise books • Lesson objectives were outline in advance • Teacher used locally available resources as teaching aids • Teacher facilitated students discussion as students were making presentation of their group work answers • Teacher summarized lesson and asked 27 formative assessment questions
Pombe	• Teacher did not have lesson plan or teaching aid • Objectives of the lesson were not identified in advance to students • Teacher did not revise the previous lesson to connect with new lesson • Teacher asked questions using 'rapid fire' style of questioning • Teacher did not identify students' misconception during the lesson • Lesson was not evaluated and she was using a book as students teaching notes	• Teacher started the lesson by revising previous lesson • Objectives of the lesson were identified before start of the new lesson • Teachers used local available teaching resources • Students took greater role during the lesson and teacher was a facilitator • There was a high rate of teacher-student and student-student interactions • Students were curious, asking questions during the lesson and teacher asked 24 formative assessment question for two lesson observed • Student learning were evaluated, lesson was evaluated • summarized and homework was provided

Name of teacher	Summary of classroom practices before PDI	Summary classroom practices after PDI
Safari	• Teacher did not revise the previous lesson and he did not use a lesson plan or any teaching aid • Teacher did not write new concepts on the blackboard to guide students misconceptions and used chorus question and answers • Lesson was not summarised and not evaluated • Students were not given the homework • Blackboard use problematic as his writing was in small font that was difficult for students to see who sat at the back of the class	• Teacher had pre-planned lesson plan and teaching notes • Objectives of the lesson were identified in advance • Teacher started the lesson by revising previous lesson by asking students questions • Teacher utilised student local environment to connect with new lesson • Teacher asked 9 formative assessment question for one lesson observed • Teacher summarised the lesson
Sungura	• Whole classroom instruction where students repeated what teacher dictated loudly • Teacher did not have pre-planned students activities • The lesson was not evaluated or summarised • Students were not given opportunity to ask questions	

Table 2. Summary of questions asked by teachers and students in each lesson observed

		Teachers names and lessons observed												
		Manimo		Tiita		Sungura		Pombe		safari		Qwary		
Subjects observed		Mathematics	Physics	Physics	Chemistry	Physics	Biology	Biology	Biology	Chemistry	Biology	Physics	Biology	Chemistry
Questions asked by the teacher	Before PDI	2	4	6	2	0	3	4	0	4	1	1	0	3
	After PDI	15		27	-	-	-	16	8	9	-	19	-	
Question asked by students	Before PDI	0	0	0	0	1	0	0	0	1	0	1	1	0
	After PDI	7	-	11	-	-	-	8	4	6	-	8	-	-

Source: Classroom observation

Results were compared and similar themes were used for report writing. In addition, the researcher also employed a code-recode qualitative strategy, where the data was analyzed first and the analysis repeated again after three weeks to see if there is difference between the first coding and the second coding. The minor differences were addressed by repeating the analysis to ensure the trustworthiness of the findings (Thorne, 2000).

1. Research findings

The key findings of the study are reported below around four emerging themes: first, evidence of improved PCK from teachers' classroom practices before and after the PDI; second, the licensed science teachers' views on the effectiveness of the PDI in meeting their PCK needs; three, the impact of the PDI on students' learning and four, student's impressions of their teachers' changed classroom practices after the PDI.

1.1. Evidence of improved PCK from teachers' classroom practices before and after the PDI

The licensed science teachers' classroom teaching practices were observed before the PDI and eight months after it was implemented to examine whether or not their classroom practices had changed as a result of the intervention. The classroom observations focused on how licensed teachers were teaching their lessons, and on teacher-student and student-student interactions during these lessons. The summaries of the licensed science teachers' classroom practices before and after the PDI presented in Tables 1 and Table 2 below suggest a distinct change in licensed science teachers' PCK from practices where there were rare interactive teaching episodes to more active involvement of learners during the classroom instruction. For example, before the PDI Manimo started a lesson without revising previous lesson, the objectives of the lesson were not stated in advance to students, he did not have lesson plan and copied notes directly from textbooks, while after the PDI before the start of a new lesson Manimo revised the previous lesson and linked it with new lesson, he utilized the students' local environment to connect with the new lesson; and he arranged students in groups to discuss the lesson concepts and provided extra explanation (see Table 1). Likewise, before the PDI another teacher Pombe typically asked questions using a 'rapid fire' style of questioning and she did not identify students' misconceptions during the lesson, but after the PDI her students took on a greater role during the lesson with the teacher as facilitator and there was more teacher-student and student-student interactions (see Table 1). Overall the teachers asked few and uncritical formative questions (such as "class have you understood? Are we together?") before the PDI but more formative questions after PDI. Here in a lesson after the PDI Pombe asks more critical questions that challenged student thinking:

Pombe: Class, what is the role of spines in cactus?

Student 1: Madam, is a specialized leaves that scare children from touching the plant

Pombe: yah, is good attempt ... who else can try

Student 2: Madam, I think it act as defense mechanism against animals that eat plants

Pombe: Yes, is a good answer ... any additional answer or point?

Student 3: Madam, I think it help to prevent water loss because if the plant has a lot of leaves it loses a lot of water.

Pombe: Yes, class … look to this cactus plant, it lack true leaves, it has spines and this help as plant self defence against herbivorous and also reduces rate of water loss. Because absence of leaves means the plant has reduced the surface area and therefore little water is lost during plant lifetime …Yes class are we together?

Students: Yes Madam

Pombe: John (pseudonym), did you get the point here?

John: Yes Madam, I am ok

Pombe: Class, if you have understood the concept … Kasim (pseudonym), can you explain why most plants that use stems for photosynthesis do not have leaves?

Kasim: Madam, I think it is adaptation strategy for plant to store more water during the photosynthesis

Pombe: Yes, it is a good answer … who else have another view? Yes Rose (pseudonym) what do you want to say?

Rose: Madam I have similar comment

Other examples of questions asked by Pombe in this interchange included: Where do cactus plants store water? What is the function of areoles in cactus plants? Give examples of plants that use the stem for photosynthesis? What are the end products of photosynthesis in plants? During the discussion students mentioned finger tree/Bush milk (*Euphorbia Tirucalli species)* as one of the plants that use stem for photosynthesis which is a very common tree in many villages across Tanzania and typically used as a house fence. Students asked some very interesting questions concerning this tree, which challenged the teacher's thinking:

Lulu (pseudonym): Madam what is the name of the milky sap produced by this [Bush milk] plant?

Pombe: Yah Lulu that is a good question! I will answer it later, let me receive other questions

Tabu (pseudonym): Madam: can you explain why this milky sap causes skin and eyes irritation?

Pombe: Today you're asking very challenging questions! Yes I will answer them together, any other question?

> *Katika (synonymy): madam what is the function of milk sap in the plant? And also cows and goat do not eat plants with milky sap why?*
>
> *Pombe: Today our main focus of the lesson is on plants that use stem for photosynthesis instead of leaves. Therefore, next period we're going to discuss the questions together, therefore, discuss in groups and you will make a presentation tomorrow.*

In a conversation following the lesson the researcher asked the teacher why he had not responded to these students questions. He replied "You know this question needs a clear focus. I'm not prepared for such questions. I will discuss it with students next period after I have made thorough preparation.

Tiita a physics teacher also asked many more questions after the PDI (see Table 2). While teaching the topic 'Simple Machines' after the PDI he asked questions such as: Describe the characteristics of a first class lever; Who can mention the characteristics of second class levers? of third class levers?; Give reasons why tongs are considered a third class lever?. The question about the third class of levers generated a lot of debate when the teacher sketched a diagram on the blackboard of a fisherman fishing in a pond using a fishing rod with a hook holding the fish. The position of effort, fulcrum and load was not clear to the students and they questioned: Where is the position of the fulcrum? Where is the position of effort? I think the hook is the load etc. Tiita responded by elaborating on the concept illustrated in the diagram with the use of the blackboard duster, ruler and desk. He explained that the effort (his arm) was between the effort and the fulcrum but the students more confused. Finally he provided another example of a spade to describe the third class of lever after which the students indicated an understanding of the concept.

Classroom teaching and learning episodes before the intervention suggest the licensed teachers possessed weak PCK while classroom episodes after the intervention indicated distinct improvement in teachers' professional teaching skills, in particular their use of learner-centred teaching approaches. More importantly, observations of their classroom practices 8 months after the intervention indicated that the licensed science teachers were continuing to use the new knowledge and skills gained during the PDI in the teaching of their lessons, which supports the claim that the intervention had a sustained impact on the teachers' PCK.

Likewise, licensed science teachers' classroom planning, in particular schemes of work indicated their lesson plans showed sustained improvement in their PCK from limited or weak to stronger PCK for inquiry-based teaching (Table 3). Comparison of extracts from the licensed science teachers planning conducted before and after the PDI using PCK rubrics (Gardner and Gess-Newsome, 2011; E. Lee et al., 2007; Park et al., 2011) indicated that the teachers' lesson planning before the PDI possessed many features of teachers with weak PCK while lesson planning after the PDI contained more features of teachers with basic to strong PCK for teaching using inquiry learning (see Table 3). For example, Pombe's teaching plans before the PDI illustrated that in the lesson covering an '*introduction to biology'* she started the teaching by '*defining the term biology, and describing importance of learning biology*' while after the PDI her lesson planning for a similar topic indicated that she used students' '*responses to make clarification on basic biological concepts', 'terminologies how to apply biology knowledge in their surroundings'* and *'guide students to summarize their responses and make conclusion of the lesson'* (see Table 3 for details of other teachers).

Table 3. Changes in teachers' planning reflecting movement from weak/limited to stronger PCK

Topic	Teacher's activities before PDI (learning outcomes)	Teacher's activities after PDI (learning outcomes)
Introduction to biology - (Pombe, Biology form I scheme of work extract)	-Define the term biology -Describe importance of learning biology	-To use students' responses to make clarification on basic biological concepts, terminologies how to apply biology knowledge in their surroundings -To guide students to summarize their responses and make conclusion -In groups students to discuss biological concepts such as living things, life cell etc.
Biology laboratory - (Pombe, FI Biology scheme of work extract)	-To describe the structure of biology laboratory -List common laboratory apparatus in the school laboratory	-To organise students study visit to other school with biology and chemistry laboratory and study the laboratory setting -In groups students to observe and discuss laboratory chemicals and apparatus
Exponents and radicals - (Manimo, Mathematics scheme work extract)	-Discuss laws of exponents by wall chart -Derive the law of exponents	-To guide students to derive laws of exponents -Students in groups discuss the applications of exponents' laws.
Binary operation - (Manimo, Mathematics scheme work extract)	Demonstrate how to perform binary operation	-Students in groups to do presentation of binary operation
Radioactivity - (Qwary, Physics scheme work extract)	-Define the radio-activity -Demonstrate to students to students how to determine half-life of radio-isotopes	-Students in groups to discuss the meaning, calculate the half-life of radio-isotopes -Students' to present the application of radio-isotopes.
Kingdom Plantae (division Coniferophyta) - (Safari, Biology scheme of work extract)	-Discus with students distinctive features of plants under division Coniferophyta	-Students to collect and observe various plants around school environment and identify the plants belongs to Coniferophyta -Students to present the main distinctive features of division Coniferophyta.

Source: Verbatim extracts' taken from teachers' schemes of work. Note the term the use of the term 'activities' in the planning documents is intended to refer to teachers' instructional strategies

These findings reveal the teachers' planning practice after the intervention reflected more inclination towards inquiry-based teaching. Most activities identified in the teachers' schemes of work before the intervention used teacher-centred teaching strategies such as defining, describing, listing, demonstrating, which are not considered participatory from the perspective of learner-centred teaching (see Table 3). For example, Safari's strategy for teaching plants in *Division Coniferophyta*as indicated in the scheme of work before the PDI tends to be teacher-centered (*discuss with student's distinctive features of plants under division Coniferophyta*), while her teaching strategy for the same topic after PDI indicated a more inquiry based teaching approach (*students to collect and observe various plants around school environment and identify the plants belongs to Coniferophyta*). The activities now involve students in more in-depth learning and understanding of science (see Table 3). Tiita teaching the topic '*Simple Machines'* to grade 8 students before the intervention, delivered the lesson by describing and mentioning example of simple machines that were found in school environment without first giving students the opportunity to identify them and the .learning objectives of the lesson were not identified to the class in advance. After the PDI, when teaching the same topic Tiita brought different samples of simple machines to the class, such as a hammer, spanner, screw driver, nail, wheelbarrow, and spade as teaching resource to facilitate his teaching. In addition, at the beginning of the lesson he outlined the objectives of the 80-minute lesson on the blackboard (*students will be able to: 1) describe the difference between simple and complex machines by giving examples, 2). Define load, effort, mechanical advantage, velocity ratio and efficiency of machines, 3). Describe the application of simple machines in the home environment)t*. This shift in teachers' practice from teacher-centered to learner-centred approaches suggests growth in the teacher's PCK for particular topics.

1.1. Licensed science teachers views on effectiveness of the PDI in meeting teachers' PCK needs

All the licensed science teachers felt their participation in the professional development workshops had improved their PCK. For example, Pombe commented that:

> *This training was awesome … especially it has improved my PCK on how to teach students using learner-centred teaching methods rather than using teacher-centred methods. Though there are some challenges in practising the learner-centred teaching methods ... (Pombe, focus group discussion)*

Safari agreed:

> *… I feel that I am a better teacher … the PDI has changed my practice because now I understand modern [learner-centred] teaching methods. I learned new teaching strategies that are useful for helping or guiding my students to understand my lesson. (Safari, focus group discussion)*

Sungura felt the PDI enabled him to distinguish between the qualities of a professionally trained teacher and those of an untrained teacher. He commented:

> *… before these workshops what I knew is that anyone teaching in the classroom is a teacher but now I know that there is a difference between the untrained teacher and the professionally trained teacher. Yes, I have learnt that to teach effectively in the classroom you need to have PCK. (Sungura, focus group discussion)*

Manimo believed participation in the PDI had improved his understanding of the link between teaching and learning and the role of formative assessment during classroom teaching:

> *… I learnt how to teach my lesson using leaner-centred teaching strategies, and how to conduct formative assessment. These workshops helped me to understand that teaching is more than presenting content to the learners but how to teach the subject content so that it is understood by the learners, that is what makes teaching a profession. (Manimo, focus group discussion)*

The findings also indicated the growth of a PLC culture amongst teachers. Manimo described how he and his teaching colleagues were now working as a community of teachers within his school and "due to interactions with other teachers in my school my weaknesses in developing students' teaching and learning activities have been minimized" (Manimo reflection notes 8 months after intervention).

On asking what specific skills they had learnt from the PDI, the licensed science teachers reported that they now knew how to prepare lesson plans and schemes of work using learner-centred teaching methods. Possessing these new skills and capabilities boosted their confidence as teachers and their ability to meet students' learning needs:

> *I learnt many things but most important is how to teach using learner-centred teaching methods in the classroom, how to prepare a good lesson … how to involve students during the lesson. I came to understand that when a lesson is well planned the teacher's confidence also increases during the teaching. (Safari, focus group discussion)*

> *… before I didn't know the importance of preparing and using a lesson plan while teaching … preparing lesson objectives in advance before going into the classroom has helped my lesson to flow well and guided my teaching … my lessons have become more focused on students' needs. I know in advance possible students' misconceptions before entering the classroom and I can address them. (Pombe, focus group discussion)*

In summary, the licensed science teachers attributed their improved classroom teaching, including how to construct lessons plans and teach lessons that were understandable to students, to the positive impact of the PDI on their PCK development.

1.2. Impact of the PDI on students' learning

The licensed science teachers also reported that their students had benefited from their participation in the professional development workshops. They observed that their students' motivation to learn, their achievement and their attitudes to learning had improved in their classrooms since they [the teachers] had started using the pedagogical skills gained during the PDI.

> *Teaching through participatory [learner-centred] teaching methods has raised students' interest. … The use of participatory teaching methods encouraged creativity and collaboration among students, which closed achievement gaps between students from different backgrounds. (Tiita, reflection notes 8 months after intervention)*

> *The students understood more easily when my teaching is learner-centred than before when I was using the lecture method … learner-centred teaching makes students more friendly and close to you, which makes it easier to deal with the problem of each student in the classroom. (Qwary, reflection notes 8 months after intervention)*

The teachers also reported that the use of students' reflective journals motivated the sharing and progression of knowledge among students in the classroom.

> *Students were very interested in commenting on their classroom reflective journals. Students formed a collaborative network of sharing knowledge during and after the lesson for doing homework. My students become very quick to ask questions and sometimes other students responded to their fellow students' questions. (Safari, reflection notes 8 months after intervention)*

> *Through their reflective journals students know that their views are going to be used to improve the next lesson and they started commenting on their classroom journals. (Manimo, reflection notes after 8 month of intervention)*

Pombe described how her students were more interested and involved in class and as a result their understanding of the lessons had improved: "… students are now interested when I apply participatory [learner-centred] teaching methods in my class, there has been some improvement of their understanding of my subject, and they are participating fully in discussion and class work" (Pombe, reflection notes 8 months after intervention). The licensed science teachers' comments suggest that students have benefited directly from teachers' improved PCK.

1.3. Students' impressions of the licensed science teachers' use of learner-centred instruction methods

Learner-centred teaching is an innovation in the Tanzanian curriculum and there is extensive advocacy in the media for this approach to be used by teachers in the classrooms – it is popularly known as '*NjiaShirikishi' in local Swahili* which means involving learners during teaching. This advocacy has generated understanding among students and they are able to describe the potential of learner-centred teaching methods for their learning. When asked about their teachers' classroom practices the students noted some of their teachers had recently started using learner-centred teaching methods. One student noticed that teachers chose to teach this way or not: "… it depends on the teacher's decision because the teacher must initiate the use of learner-centred methods. If a teacher is not interested in using learner-centred methods, he or she will not ask you to work in groups"(Kasim, Form 3 student from Hewasi Secondary School, focus group discussion).

There were favourable comments from some students about learner-centred teaching methods because they understood more when the classroom teaching was learner-centred. They recommended that these methods should be practiced by all teachers in their schools.

> *... I like very much learner-centred teaching methods because you get the opportunity to share your ideas with other students in the classroom. For example if don't understand a concept in the class when the teacher is teaching you can share your ideas with friends and you will understand and learn a concept … (Philomena, Form 2 student from Hewasi Secondary School, focus group discussion)*

The opportunity to be active in learning and collaborate with peers was another perceived bonus of the learner-centred teaching method by the students since it reduced anxieties and allowed them to share knowledge with friends.

> *Learner-centred teaching makes you intellectually active; it removes loneliness and fear during teaching and learning in the classroom. For example, if you don't have any idea about the topic and if you ask your friends who understand such an idea you will also understand and this helps me to learn easily (Ghaghara, Form 3 student from Hewasi Secondary School, focus group discussion).*

One student commented that learner-centred teaching methods bring students closer to their teachers and help to improve students' attentiveness in the lesson:

> *You know sometimes when the teacher is teaching and he [she] is not interacting with the class you might be physically in the class but your mind is out of the class thinking about something else … when teaching is using learner-centred it helps to bring you back into the classroom and concentrate. (Samwel, Form 3 student from Nungu Secondary School, focus group discussion).*

Some students identified an improvement in the quality or depth of their learning. Here Gisa explains how the learner-centred approach helps to reduce misconception(s) during teaching:

> *… it is a good method because it helps students to understand the concept easily, and you can use your friends' ideas to correct your misconceptions. You get the truth about what you're learning from your friends' contributions. (Gisa, Form 1 student from Tlawi Secondary School, focus group discussion).*

Fatma also commented that when teaching is learner-centred there is deep learning.

Participatory [learner-centred] teaching methods help to build students' confidence in the subject, because when everyone in the classroom chip-in what she [he] knows you get new ideas from one or two people [students] and that will add to the little you know so that you will deeply understand the concept the teacher is teaching. (Fatma, Form 1 student from Katani secondary school- phase 2 focus group discussions)

Overall the students appeared to value the use of learner-centred teaching methods when used in their classroom teaching and recognised the positive impact on the nature of their learning.

2. Discussion and conclusion

The findings from this study indicate that a PDI informed by the tenets of situativity theory, which engages teachers in a collegial collaboration within professional learning communities in school-based contexts, can enhance the PCK of unqualified licensed science teachers significantly. Improvement of the teachers' PCK in this study was evident in the participant teachers' changed classroom practices (such as classroom planning and teacher-student interactions) as they moved from traditional transmissive teaching methods to more learner-centred, inquiry-oriented teaching approaches. Such movement suggests fundamental changes in their *orientations towards science teaching*(Magnusson et al., 1999) that now reflect more highly developed PCK i.e., belief in learner-centred pedagogy (Vavrus et al., 2011). As a result of the controversial nature of PCK various strategies/techniques have been adopted to measure PCK including: observation protocols, semi-structured interview, content representation concept mapping and others (Baxter and Lederman, 1999; Rohaan et al., 2009). Gardner and Gess-Newsome (2011) suggest that PCK can be viewed as a continuum from weak to strong and measured using indicators of weak through to strong PCK within the frameworks of PCK models like that proposed by Magnusson et al. (1999). The application of this continuum view of PCK, which necessitated the identification and selection of indicators for portraying strong versus weak PCK, proved a useful way of detecting changes in the licensed teachers' PCK. These changes, for example, indicated the licensed teachers initially lacked strong dispositions for student-centred inquiry learning in science while their rhetoric and practices after the intervention indicated movement towards stronger dispositions.

The change in the teachers' belief system is significant because this PCK component helped to shape how they subsequently planned, enacted and evaluated their teaching and professional learning processes. Their improved planning skills meant the teachers' lessons were better organized, and classroom teaching was more inquiry-oriented and student-focused with greater use of locally improvised teaching and learning materials and formative assessment to monitor learning. This finding concurs with the study conducted in Sweden byOlander and Olander (2013) who argued that professional development guided by a collaborative and iterative working model helps teachers to develop their "pedagogical content knowledge (e.g. how to design lessons that offer students the opportunity to express and develop their previous understandings and to understand whole/part relations and organizational levels)" (p. 210). These developments in the licensed teachers' *knowledge of curriculum, knowledge of instructional strategies, knowledge of learners and knowledge* *of assessment* can be considered enhancements to their overall PCK because together they represent closer alignment of the teacher classroom practices with the intent of the reform-based national curriculum and the features of strong PCK as identified in the literature. The findings from classroom observations, teachers' focus group discussions, teachers' reflection notes and students' focus group indicated the PDI impacted on the licensed teachers' traditional teaching practice changing their views of learners as passive receivers of knowledge to partners in learning.

Previous studies (e.g., Borko and Koellner, 2008; Owen, 2004; van Es, 2012) agree that PLCs can effectively foster teachers' professional knowledge and improve their classroom practice. This study's findings supports the view that a PDI facilitates teachers' construction of knowledge and enhances their PCK development when itis: contextualized in teachers' working environments; engages teachers in an activity they believe is authentic to their profession; and has activities that encourage the active engagement of teachers in a collaborative community sharing knowledge and skills (Anderson et al., 2000; Borko and Koellner, 2008; Ghefaili, 2003). The PDI in this study drew its strength from consideration of "what sort of local knowledge, problems, routines, and aspirations shape and are shaped by individual practices and beliefs" (Opfer and Pedder, 2011, p. 379) and its use of a circular feedback loop from workshops, to classroom internship practice to PLC discussions and back again, which added value to the professional learning compared to traditional professional development consisting of one-stop workshops. The literature consistently supports the notion that an effective PDIis carefully planned such that it: involves teachers in their own needs assessment; is conducted over a significant time period; allows teachers to enter into discussion with peers; put into practice what they learn in workshops; to experience school-based peer coaching within the same school or department; and to share practices (Opfer and Pedder, 2011; van Es, 2012; Wayne et al., 2008).

Changes in the students' learning dispositions in this study, from essentially disengaged learners prior to the PDI to more active and involved learners post-PDI can be interpreted as a reflection of their teachers' implementation of the new learner-centred teaching methods they had learnt during the PDI. These findings concur with previous work by Nunokawa (2012) who reported that teachers who participated in professional development training felt more confident in their abilities to implement new instructional strategies gained from the professional development which in turn had a positive effect on student learning.

In summary, this study has demonstrated that professional development built around a culture of teachers working collegially within their own context can positively impact on the PCK of unqualified teachers recruited via an alternative route approach. Key to this improvement in their PCK is a paradigm shift in the teachers' orientations to and beliefs about science teaching from traditional teacher-centred pedagogy towards learner-centred teaching methods. More importantly, this study provides promising evidence that the professional learning needs of unqualified science teachers can be enhanced while they are still working in classrooms. It also provides preliminary evidence that a PDI underpinned by situativity theory (Durning and Artino, 2011; Schunk, 2012; Wilson and Myers, 2000), and utilizing this PLC model of needs based and purpose-built teacher development has the potential to effectively meet the PCK needs of any teachers who are precluded from formal pre-service teaching education, like the Tanzanian licensed science teachers.

3. Implications and recommendations

Despite the small size of this study, the findings have practical implications for improving the status and quality of science teaching in all countries where dependence on the recruitment of unqualified teachers has limited the ability of teacher educators to train sufficient and adequate teachers for the growing secondary education sector. This study has provided evidence that suggests the underdeveloped PCK of all teachers recruited via alternative routes can be improved using in-service PDIs of the type developed in this study, that is, focused on authentic pedagogical problems, and informed by best practice within school-based PLCs. The unqualified licensed science teachers in this study greatly appreciated and benefited from professional development that used collaborative activities, such as the sharing of classroom teaching practices, within a learning community of teachers. A similar observation was also reported in the recent study by Jones et al. (2013) who noted that many teachers “value the opportunity to collaborate in the improvement of science … Participants reported changes in their science assessment strategies, planning for science lessons, instructional innovation, and knowledge of science resources as a result of participating in the science PLC” (pp. 16-17). It seems teachers exposed to and involved in PLCs while working in schools view them as a promising solution to their underdeveloped PCK. Effective school-based professional development support such as the PDI investigated in this study can help unqualified science teachers develop and use learner-centred methods of teaching to improve their teaching and students’ learning outcomes.

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Appendices

Appendix 1. Refined content of the professional development workshops

	Module	Content covered	Teaching and learning strategies used to teach the module contents
Workshop 1	Module 1: Understanding of a professional learning community	• Concept of a PLC • Characteristics of a PLC of teachers • Role of a PLC in addressing teachers' PCK and students' learning outcomes	• Groups work presentation (after reading PLCs articles) • Critically examining two lessons as a PLC of science teachers and then members identified some possible students' naïve ideas. • Power point presentation (researcher)
	Module 2: Lessons planning	• Preparation of specific learning objectives and lesson competencies • Selecting appropriate action verbs (Blooms Taxonomy) • Preparation of lesson plan • Selecting teaching approach according to class size, age and interest • Presentation skills - loudness of voice, positioning, mannerisms, questioning strategies including use of waiting time and reinforcement.	• Evaluating samples of old lesson plans and schemes of work • Teaching of sample lesson to the group • Panel discussion on the ways of improving the presented lesson • Writing a reflection on the presented lesson • Power point presentation (researcher)
	Module 3: Characteristics of learner-centred teaching	• Differences between learner-centred and teacher-centred approaches to teaching • Characteristics of learner-centred teaching • Strategies of teaching science using a learner-centred approach • Assessment of the learner–centred teaching approach	• Group work presentation and discussion • Micro-teaching of learner-centred science lesson • Writing reflection on each lesson

Workshop 2	Module 4: The conceptions of teaching and learning science	• Examining the concept of "teaching" in relation to learning (i.e. is it to promote transmission, interaction, or transformation; is it an art or a science?) • Describing and demonstrating interactive and transformative approaches of teaching (group tasks, plenary discussions, panel discussions, role playing, dramatization, case studies, etc.).	• Group work presenting summary of the articles. • Demonstration of 'teaching' conception by micro-teaching of selected topics in science subjects • Power point presentation
Workshop 3	Module 5: Reflective practice in teaching science	• Exploring the purpose of a reflective journal • Learning to reflect on practice • How to use "EXPLORE' as a reflective technique. EXPLORE is an acronym for "Examine," "Pair," "Listen," "Organize," "Research," and "Evaluate."	• Power point presentation about the concept of a reflective journal • Reading journal articles about reflective journals • Participants to develop reflective journals for teaching their subjects
	Module 6: Categories of the knowledge base of teaching science	• Explore the different knowledge base categories for teaching science • Examining the major sources of the knowledge base of teaching • The use pedagogical reasoning in teaching science topics	• Workshop participants' presentations of a summary of the articles for workshop discussion • Power point presentation (researcher)
Workshop 4	Module 7: Formative and Summative assessment	• Discuss and practice formative assessment through oral and written questioning and observation • Examine summative as opposed to formative assessment • Setting and management of individual and group homework tasks and quizzes/tests.	• Group work presentation and discussion • Teaching a lesson in classroom and demonstrating formative assessment while teaching • Workshop presentation (power point presentation) • Reading formative and summative assessment selected articles
	Module 8: Portfolio as an assessment tool for science teacher	• Explaining the purpose and uses of a teaching portfolio • content of a science teaching portfolio • Strategies for organizing a science teaching portfolio	• Licensed teachers' group work presentation (workshop approach) • Power point presentation (researcher and participants) • Developing a summary from journal articles about teaching portfolio.

Appendix 2. Professional development workshops teachers' reflection notes guide

1. How would you describe this session today in improving your professional teaching knowledge?
   - What are the weaknesses of this workshop session today?
   - What are the strengths of this workshop session today?
2. What important professional skills you have learned in the workshop today?
3. Is this workshop relevant to your pedagogical content knowledge needs? Explain briefly
4. How would you describe the relevance of teacher's social networking in this workshop from other schools?
5. Give you general comments that you think are important to share with others before we proceed to next workshop session.

Appendix 3. Focus group discussion guide after PDI

1. Please share with me what you have learned from participating in the professional development intervention in terms of:
   - Relevance to your pedagogical content knowledge needs?
   - Quality of material in broadening your concepts on teaching students?
   - Specific ways you think you have changed your classroom practice?
2. How can you describe the professional learning community networking and sharing of materials/concepts between teachers from your schools in achieving the following:
   - Is networking helpful for subject content knowledge growth?
   - Do you think this intervention has helped you to acquire pedagogical skills?
3. In what ways do you think you have benefited from professional development intervention in acquiring learner-centred teaching pedagogy?
4. What are the strengths of this professional learning intervention?
5. What are the weaknesses of this professional learning intervention programme?
6. Do you like this intervention to be continuous in your school? Why/why not?
7. What should be done in the future if we need to have school-based professional development programme sustainable for licensed teachers?

Appendix 4. Students' focus group discussion guide after PDI

1. How would you describe this lesson taught today?
   - What do you think you have learnt in today's lesson?
   - Did you enjoy? Why?
2. Have you heard about the learner-centred teaching methods?

- Can you explain?
- Do you like learner-centred teaching methods? Explain your answer?

3. How do you describe the use of learner-centred instruction during the teaching and learning processes?
4. How often your teachers have been using learner-centred teaching methods?
    - Are all teachers using learner-centred teaching methods?
5. What are the challenges of learning science subjects using learner-centred teaching methods?
6. Would you explain the advantages of learner-centred methods over teacher-centred teaching methods?
7. There is claim in the literature that students do not like learner-centred teaching methods?
    - Is this claim relevant? Explain?
    - There is claim that Form I and II students do not like learner-centred teaching methods. Is this claim relevant? Explain?
8. Is there anything further anyone would like to add, that you feel you've not had a chance to say?

Appendix 5. Post-professional development intervention reflection questions for licensed science teachers

1. Did the content of the professional development intervention make sense to your teaching practice? Please explain.
2. Did the facilitator knowledgeable and helpful in teaching the professional development content? Explain
3. Did you achieve some of your professional development needs because of this professional development intervention? Explain
    - Pedagogical knowledge
    - Subject content knowledge
    - Pedagogical content knowledge
4. What are some other ways that the professional development had important impact on your practice?
5. Did you receive support from your school leadership in implementing the new skills you have learned? Explain
6. Did you share the new skills you have learned with other science teachers in the school? Explain
7. Did you practice the new skills you have learned? Explain by examples

8. What are some other ways that the professional development had important impact on student outcomes in your classroom?
9. In you view do you think this professional development programme helped you to develop teacher network community? Explain?
10. Please describe any impediments (e.g., lack of materials, support, resources, and training) that need to be addressed for consistent, successful implementation to be achieved.
11. Please describe strategies that you used to make implementation easier and or more successful.
12. General comments: