Physical Sciences student teachers training: theoretical and practical aspects

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ABSTRACT
This article presents the general theoretical and practical axes for the training of physical sciences teachers who are trained in diverse settings, using the example of the National University of Lesotho student teachers. The article first presents the general structural features of teacher education in this institution. In the subsequent section, the particular dimensions of this process are approached through the concepts of pedagogical content knowledge/didactic transposition

KEYWORDS
Physical Science teacher, teacher training, pedagogical content knowledge, didactic transposition

RÉSUMÉ
Cet article présente les axes théoriques et pratiques généraux de la formation des enseignants de sciences physiques formés dans divers contextes, en utilisant l'exemple des étudiants enseignants de l'Université nationale du Lesotho. L'article présente d'abord les caractéristiques structurelles générales de la formation des enseignants dans cette institution. Dans la section suivante, les dimensions particulières de ce processus sont abordées à travers les concepts de pedagogical content knowledge/transposition didactique.

MOTS-CLÉS
Enseignant des sciences physiques, formation des enseignants, pedagogical content knowledge, transposition didactique

INTRODUCTION

In a more general context of searching for the deficiencies that lead to the failure of student science teachers to adequately use in their classroom practice what they had been taught in their theory courses, the teacher preparation at the National University of Lesotho (NUL) was used as an example. The general design of an evolving research is to capture the ideas and opinions of teacher educators (TEs), student teachers (STs), teachers of teaching practice (TPTs) and regular practicing teachers (RPTs) based on their experiences. The specific research topic was the preparation given to science teachers when learning to teach in specific science subject areas and how student teachers highlighted and valued the results of this overall preparation during their teaching practice.

A previous paper highlighted the central concepts used in this direction: teacher preparation, STs' learning to teach, development of their professional knowledge, teaching practice and participants' perspectives on the whole situation (Mabejane, 2014). The main focus of the whole effort was on two particular and critical aspects of preparing science teachers for practical teaching. First, the methodological and pedagogical strategies adopted to develop STs' professional knowledge during their university courses and their practical training in a real school environment. At a second level, identifying the content offered in the curriculum courses they attended, which STs later drew from and used in their classroom practice. This article (Mabejane, 2014) discussed the basic concepts underlying the study and in the context of which the relevant research questions could be posed. So, this paper discusses the concepts and theories that underpin the framework of the study in relation to the relevant literature. The study focuses on the initial teacher training (pre-service) stage for undergraduate science teachers at NUL. To set the stage for the discussions that follow, the model of science teacher training taken at NUL as the study institution is illustrated in Figure. However, let us begin with a brief look at the main theories underpinning the key concepts utilised in the general framework of the research.

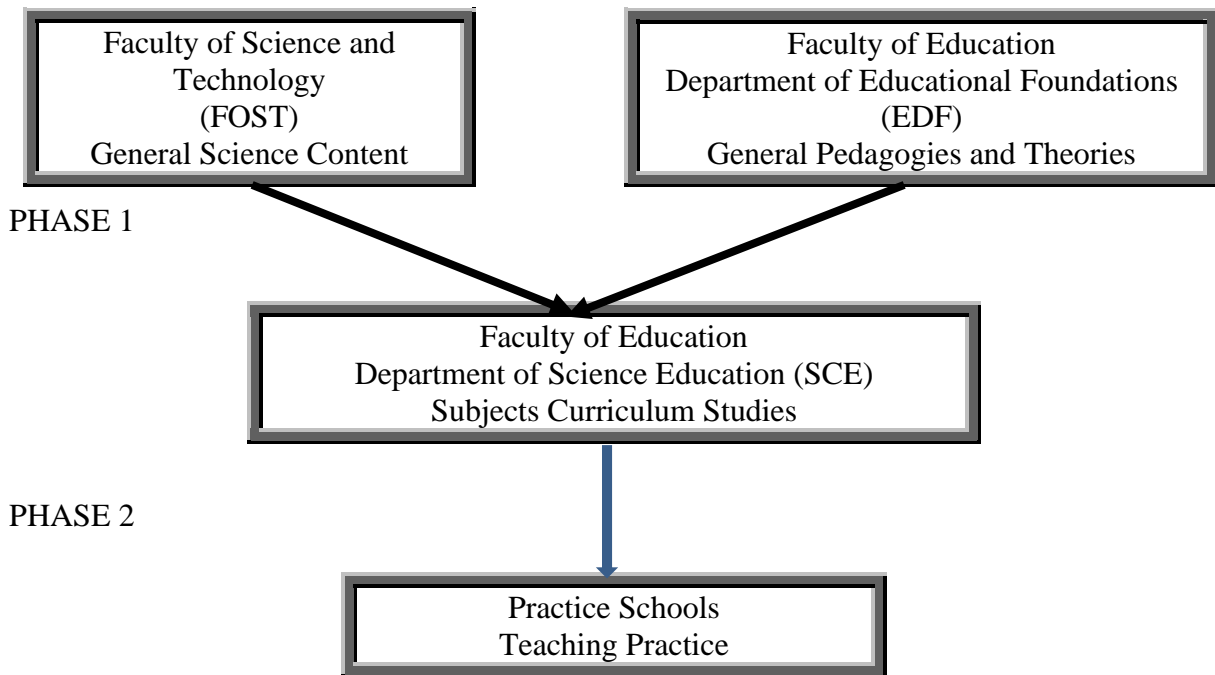## PRE-SERVICE UNDERGRADUATE SCIENCE TEACHER TRAINING PROGRAM AT NUL

At NUL, teacher training is the responsibility of the Faculty of Education (FED) which comprises three departments; Science Education (SCE), Language and Social Education (LASED) and Educational Foundations (EDF). The EDF department basically offers the general educational theories and pedagogies for the two sister departments. The general content in Science is offered by the Faculty of Science and Technology (FOST). The pedagogies related to specific science subject content to be taught in schools are dealt with in the Curriculum Studies courses offered by the Science Education (SCE) Department. Teaching practice (TP) that lasts for ten weeks completes the training in the final year.

It can be seen from the figure that the subject matter (content) and the general pedagogical knowledge in this case are offered by the departments which belong to different faculties. The academic science courses offered to the education students are those done also by the students following the general science degree. One could assume that what is being offered there is not necessarily what the STs would be actually teaching thereafter. The general pedagogies too do not essentially consider the specific needs of the science disciplines. To bring the content and pedagogies to the context of science teacher learning and teaching, the contextualization of knowledge from these departments, SCE offers the Curriculum Studies courses (methods courses). In the last semester of the whole training comes ten week teaching practice (TP) in schools. The model that represents the traditional perspective and the one found to be the most common worldwide.

The depicted picture in Figure illustrating the training model for prospective science teachers confirms the view expressed by Ball, (2000, p. 242) attesting: "*... teacher education throughout the 20th century has consistently been structured across a persistent divide between subject matter and pedagogy*". Other examples of such divide given include those in institutional structures, universities and schools, domains of knowledge in teacher education curriculum, and academic disciplines corresponding to school subjects that would be taught after training. In this case there seems to be a divide at all mentioned levels. She further points out that the already existing chasms are complemented by fragmented practice experiences which in themselves fragment teaching. We do consider micro/peer teaching and teaching practice in schools as fragments of practice experience especially when the practice done on

and with peers during on-campus training does not resemble the practicalities of actual school situation.

FIGURE

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┌─────────────────────────┐        ┌─────────────────────────────────┐
│  Faculty of Science and │        │      Faculty of Education       │
│       Technology        │        │ Department of Educational       │
│        (FOST)           │        │ Foundations (EDF)               │
│ General Science Content │        │ General Pedagogies and Theories │
└─────────────────────────┘        └─────────────────────────────────┘
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PHASE 1

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              ┌────────────────────────────────────────┐
              │        Faculty of Education            │
              │ Department of Science Education (SCE)  │
              │       Subjects Curriculum Studies      │
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PHASE 2

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              ┌────────────────────────┐
              │     Practice Schools   │
              │    Teaching Practice   │
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Pre-Service undergraduate Science Teacher Training Program at NUL

As a common procedure in teacher education programs worldwide, the teacher training program at NUL offers content, pedagogies and educational theories courses in a conventional face-to-face mode of delivery on campus and teaching practice in schools (Lewin, 2004). The content courses are intended to ground student teachers in the knowledge of the concepts in the subjects they would be teaching in schools. The educational foundations/professional studies knowledge considers general aspects of philosophy, history, sociology of education and psychology of education, the knowledge underpinning the processes of teaching and learning. The pedagogies are to enable student teachers to teach the subject matter for students to understand and appreciate what is being learned.

In the course of face-to-face phase teaching, STs are afforded an opportunity to practice some basic skills of teaching through micro/peer teaching (Zacharos, Antonopoulos, & Ravanis, 2011). In particular they do peer-teaching in the Curriculum Studies courses. The evidence of the impact of micro-teaching in preparing prospective teachers in the art of teaching, developing their teaching capabilities and confidence is revealed in the work by several researchers through the views of TEs, STs and researchers' observations (Ghanaguru, Nair, & Yong, 2013).

GENERAL THEORETICAL FRAMEWORK

The observed pervasive incompetence with both pre-service and in-service teachers in classroom teaching still abounds despite the various efforts made in many countries to improve teacher representations about scientific and/or school knowledge, teacher education and teacher preparation programmes (Ball, 2000; Darling-Hammond, 2000; Zeichner, 2010). It has thus been a concern over the years why teachers fail to connect the learned theory with their practice

hence the "perennial" gap expressed by Korthagen (2010) enduring. In this section I discuss the literature related to the concepts of teacher education and teaching, teacher preparation, learning to teach, teacher knowledge, teaching practice and the theories underpinning this study.

During practice in schools STs are supported and guided by TPTs who are expected to act as professional guides and educators due to their assumed experience and expertise. Stones and Morris cited in Kirk (1986, p. 16) however characterize this approach as "sitting with Nellie". The meaning as quoted by Kirk being: "Nellie is a factory worker who has been doing the job for years to whom new recruits are attached while they learn the job". Kirk attests that "sitting with Nellie" has proved to be "an extremely inefficient and wasteful method of training, haphazard, and lacking the capacity for the systematic development of teaching skills". It could only be taken as part of or the probable cause for the discernable gap between what might have been learned and the practice observed with the science student teachers at NUL after it had been found from the concerned parties. Since no form of research on the impact of "Nellie" could be accessed in Lesotho, it was decided that it might be worthwhile to find out about the situation in connection with the TPTs and STs' learning to teach during TP. Student teacher and TPT in their practice are both supposed to be supported and guided by the Handbook designed by FED. The teacher educators offer their support through the visits to STs in their practice schools to observe them in action so as to assist them on the ground also as a way of extending the training and enhancing their professional development, and for assessment. The next section discusses the main theory upon which the study is based, PCK and/or Didactic Transposition.

Pedagogical content knowledge / didactic transposition in relation to the study concepts

Pedagogical content knowledge (PCK) and/or Didactic Transposition (DT) is the main theory underpinning this study as a domain of teacher knowledge that is crucial for teacher professional development. It was considered how it was dealt with including its components in teaching STs to teach and their application of it in practice. It was not necessarily studying how it developed with STs' learning, one reason being that they were likely to handle a range of topics as the schools decided during TP. That was due to the view that PCK/DT development has been said to be topic specific (Shulman, 1986, 1987; Ravanis, 2009; Vellopoulou & Ravanis, 2012). Since PCK embodies CK and PK in action all taken as teacher knowledge, PCK is specifically mentioned where teacher knowledge is enacted.

PCK is undoubtedly a form of teacher knowledge that has been proved to have a significant impact on effective teaching and it is deemed an important goal for teacher professional development programs (Van Driel & Berry, 2012). However, the study on this concept in Lesotho is still insignificant. Since no research has critically investigated the relationship between the training methodologies on student teachers' performance during teaching practice it was hoped that the findings of this study could reveal the actual aspects of teacher knowledge domains and components that STs' find helpful/not helpful; and as a result employ/not employ in their classroom teaching during TP. No studies undertaken on PCK in relation to NUL teacher training programs and trainers' perceptions and practices of it could be accessed too. With the LCE and the Colleges in the countries involved in Multi Site Teacher Education Research (MUSTER) project, it has been found from the reviewed curriculum materials that some of the key dimensions of PCK/DT are missing (Lewin, 2004).

PCK could be taken to happen in two stages, starting with lesson planning which portrays a theoretical or hypothetical version. This is said because in the planning one considers all relevant factors associated with teaching and learning which again we consider to constitute a teaching context. As early as when a teacher plans for her/his teaching, a lot of cognitive teacher knowledge comes in. It gets manipulated (conceptualized, organized and transformed) influenced by personal attributes, beliefs, attitudes, conception of teaching and learning,

experiences etc. on the basis of which a teacher makes decisions for the particular lesson being planned. The importance and effect of lesson planning has been researched, and the lesson plan has been used as a tool for the professional development of teachers and assessment of PCK (Prescott, Bausch, & Bruder, 2013; Valk & Brockman, 1999). Problematic as the lesson plan has proved to be it remains a crucial tool for a teacher. Lesson planning in itself is a difficult skill that student teachers take time to grasp, drawing and implementing. But the importance of the lesson plan in guiding and directing teaching cannot be underestimated.

We take it that for teachers to be able to formulate and organize the subject content to be taught, they should be having a good understanding of that content borne in the curriculum and the curriculum itself. They should know the demands of their subject curriculum especially the syllabus in those countries where national curricula are used. The syllabus in its goals, aims, objectives and learning outcomes stipulates why a particular subject/topic should be taught, all targeting to benefit the student. This knowledge a teacher would then convert into a teaching curriculum, which one may equate to what Del Pozo, Pórlan and Rivero (2011) call "school knowledge". The content in the syllabus does not stipulate among other things how the topic concepts should be ordered and treated for students' learning. Neither does it give specific activities, explanations, analogies, examples, representations and so on, matching them with the stipulated aspired benefits for students. This is the work of a teacher which is quite challenging.

The lesson plan format that the STs get trained on at NUL looks into issues such as, level of learners, subject to be taught and time - bearing duration, lesson objectives, students' prior/assumed knowledge, classroom organization/setting, materials/teaching aids, method(s), content, teacher and students' activities, assessment, reflection on the lesson and the means to improve all of which in our opinion build a context of teaching. These components of the lesson plan are entailed in PCK/DT stated by Shulman and other proponents of the notion (Abell, 2007; Gess-Newsome, 1999; Johnston & Ahtee, 2006; Magnusson, Krajcik, & Borko, 1999; Vellopoulou & Ravanis, 2010). Since PCK brings together the theoretical knowledge and practice, the section that follows looks into the issue of practice and theory.

Practice and Theory in relation to the study concepts

As did Allen, Ambrossetti & Turner (2013), it was decided to follow Zeichner (2010) in using the term "theory" as representing the broad range of concepts and skills associated with the declarative and procedural knowledge taught to student teachers on campus during coursework training; and "practice" referring to the classroom pedagogy and activities of the teacher during teaching practice also referred to as field experience or practicum in some parts of the world.

In Lesotho as it seems a common observation elsewhere, science teachers do not perform as expected. As a result, there is a need to help pre-service teachers learn to teach effectively (Grossman, 1990; Magnusson et al., 1999). The observation made by Ben-Peretz (2011) from the analysis of studies made on PCK/DT that it had been mainly on the western context and culture justifies the concern raised by Lewin (2004) that the educational ideas and materials used in the countries he is working with in Africa are usually derived from the West, hence detached from the context and culture of the African teachers and teacher educators. Thus, the teacher base knowledge gets more trivial for student teachers and probably not even fully understood by the teacher educators. It is therefore worthwhile to study PCK/DT in different contexts and cultures. Ben- Peretz goes further to indicate that in those studies, there had not been a look into what exactly is taught in teacher preparation courses that prepare prospective teachers' development of their PCK, the situation that applies in Lesotho. Neither was there any that had studied teacher knowledge in relation to NUL teacher educators' perceptions and practices thereof.

Teacher trainees out in schools have special needs and requirements that could be met if there could be some evident and strong support and supervisory systems which keep the trainees and trainers close together even at the distance. For example, the question of students' difficulties in specific learning issues in Physical Sciences (Kada & Ravanis, 2016; Kokologiannaki & Ravanis, 2012; Ravanis, 2013) is a top issue that requires constant communication. With the support systems in place there could be a possibility to avoid the situation described by Lewin (2004) in which STs have limited support. This view further triggered the desire to explore the situation in teacher training at NUL because literature reveals that there are those countries such as Finland (Lanas & Kelchermans, 2015, p. 22) which has "the most successful education systems in the world" including teacher training/preparation programs the impact of which is manifested by successful student performance which is the aspect of students' learning easily accessed and desired by the public.

Teaching practice/practicum has been proved to have challenges (Hoffman et al., 2015; Ozdemir & Yildrim, 2012) and in establishing what may be leading to STs' inability to successfully implement what they have been taught makes this phase a relevant part of this study site. It is therefore inevitable that there are interactions between TTIs and practice schools, the partnership that has both benefits and challenges (Avalos, 2011; Day & Smethen, 2010; Hoffman et al. 2015; Zeichner, 2010). This link is being explored in this study to establish its influence in enabling the prospective teachers to develop the ability to construct well thought out and planned logical practices as it is part of learning to teach, hence developing STs' PCK.

The UNESCO study conducted in 2013 with science and mathematics teachers at both primary and secondary level in Lesotho, to establish the challenges they encountered in their teaching revealed that even the teachers who had been in the field for a number of years, still had problems similar to those of the STs. Of the challenges that came out significantly were teachers' not being able to interpret the syllabus as part of the curriculum and guiding tool for their teaching, inability to effectively correlate content with employed pedagogies, also mentioning some topics that gave them a problem to teach because they themselves did not quite understand some concepts embodied in them. They failed to vary teaching strategies to make learning meaningful for students. That confirmed the findings of the previously conducted needs analysis study for improvement of teaching in core subjects; viz. Mathematics, Science, English and Sesotho (Kingdom of Lesotho - Ministry of Education and Training, 2006). Could that be saying that there are times when even experience fails to be a better teacher? On the contrary, research by Boyd et al. in Shuls and Ritter (2013) indicates that teachers do improve fast in their practice especially in the first three years of teaching. It is felt that teaching practice should be marking the beginning of that stage of accelerated teacher professional improvement, the induction stage. In Germany in its 5 year program, the first year of teaching forms part of the formal pre-service stage.

Support and supervision in the initial stage are crucial throughout the process of teacher development (Brandsford, Brown, & Cockling, 2000; Donovan, Brandsford, & Pellegrino, 1999; McCarthy & Quinn, 2010). With the TPT in place, TP Handbook and the visits by NUL supervisors, one would argue that there are support structures in place. TPT as the experienced practitioner is expected to provide regular essential support and supervision to the student teacher. According to the expectations expressed in the section on the roles of TPT in the TP Handbook (National University of Lesotho, 2015, p. 13) they are supposed to observe STS' classroom teaching after which they are to fill the record of their discussions in the Observation Record sheet (the sample on p. 19). Those forms were to be included as part of ST's TP file. But if, even with training and the support mechanisms provided the STs still showed the apparent deficits, probably guidance and support ought to be the 'ongoing must attributes' of the pre-service stage of teacher professional development. That could be confirming that the support mechanisms are not in themselves the required content and processes. And as Martin,

Snow and Torrez (2011) point out, the support structures could be enhanced by constructing rich supportive contexts with transformative settings that enable teacher learning. That might probably help to enhance the development of PCK in and from practice (Ball & Cohen, 1999) despite the complexity and unpredictability of classroom practice.

Those observations triggered a desire to look closely into pre-service training course content and methodologies used, to establish their correlation with the practice by STs and TPTs in schools. With the reported inadequacy in STs' classroom practice could it suffice to say that the three major sins identified by Varela (2012, p. 17) with the in-service training of teachers: "(1) a one-size-its [sic]-all mentality; (2) in-service isolated from daily classroom practices; and (3) a lack of follow-up" hold for pre-service training? This study was hoped to help find out if some elements of these questions hold for pre-service teacher training of science teachers at NUL.

This marks the importance of not conceptually bringing together theory and practice, but actually enabling prospective teachers to professionally and purposefully match the content and pedagogies in their classroom practice. There is therefore a paradigm shift from theory to practice notion to what one might term "give and take" as a way of marking the dialectic feature desired balance. In other words it could be practicalising theory and theorizing practice therefore leaving no room for theory and practice as separate entities. What is being practiced is actually a blend of the learned subject matter and the pedagogies of meaningfully conveying concepts to the students. That professional practice displays teacher knowledge. Connecting learned theory to practice does not necessarily mean theory to practice as observed in the traditional model of teacher training. It is therefore worthwhile to take a critical look into each one of these facets, their connections and the impact of one on the other to be able to foster their reciprocity. That could be achieved through ongoing reflection which is then discussed in the next section.

Reflection in Teaching and Learning in relation to the study concepts

Reflective practice is regarded a crucial aspect in teacher development programs to enhance the quality of classroom teaching and student and teacher learning leading to the development of alternative pedagogical practices and abilities in order to react accordingly to unexpected occurrences (Darling-Hammond, 2005; Zeichner & Liston, 1996). The Handbook guiding NUL STs' practice in schools advocates learning from experience (National University of Lesotho, 2015) following the general notion that reflection is one of the driving forces of professional development.

Taking action on the basis of the results of their reflection, STs would be practicing a variety of ways to choose and organize subject matter, transforming it to suit a specific context and at any specific time. That practice leads to improvement of CK, PK and PCK resulting in professional development as well as building more on one's repertoire of experiences and expertise with teaching (Darling-Hammond & Bransford, 2005; Zeichner & Liston, 1996). Reflection thus becomes a crucial attribute of effective teaching and learning which the STs need to be prepared for and guided on throughout their training (Boilevin & Ravanis, 2007; Collier, 1999; Freese, 2006; Korthagen, 2001, 2004; Korthagen & Vasalos, 2005; Loughran & Corrigan, 1995; Marland, 1993; Orland-Barak & Yinon, 2007; Pollard, 2002; Ravanis & Pantidos, 2008; Ross & Bruce 2007; Sarivan, 2011; Yost, Sentner, & Forlenza-Bailey, 2000).

For student teachers' reflection, varying means have been expressed, designed and used and have proved to be effective, including tools such as journal entries (Loughran & Berry, 2005), portfolios (Groom & Maunonen-Eskelinen, 2006; Kaasila & Lauriala, 2013; Stuart, & Thurlow, 2000), video analysis (Kleinknecht & Gröschner, 2016; Santagata & Angelici, 2010), lesson plan (Majzub, 2012; Ravanis, 2010; Sigauke et al., 1993; Ward & McCotter, 2004). With

the various models of reflection and the seemingly broad reflection with teacher training program at NUL, the outcome of the research would indicate the modes and stages/levels reached by those student STs. "Reflecting on practice is a complex task requiring observation and reflective skills" (Leavy & Hourigan, 2016, p. 162). Being observant and conscious to all aspects of teaching and learning would form a ground for reflecting on the identified issues upon which a teacher would work out the alternative means for better performance and outcomes. Any form of skill is better developed through regular, organized, guided and comprehensive practice as the use of intervention tool for reflection and designing the means to improve as proved beneficial to STs' professional development (Watts & Lawson, 2008).

CONCLUSIONS

The concepts and their practical dimensions developed in this article are related to the pre-service training of student science teachers at NUL and have been the subject of study in the international literature in recent years. Obviously, the issue is huge and takes on completely different dimensions in different cultural, social and economic contexts. Because the conditions in which future teachers are trained are completely different, for example, in Africa and Europe. Assuming that the general theoretical axes are a product of agreement in the wider scientific community of Science Education, the local specificities need systematic study and research in order to be able to address the particular problems and support an effective education of future teachers. This issue also takes on special dimensions for teachers of different disciplines, such as those of Physical Sciences, since their future work has special needs and requirements. A next phase of research is already underway in this direction.

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