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**Content Knowledge of Pre-Service Natural and Life Science Teachers: As Illustrated by the Case of Photosynthesis and Respiration**
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# Content Knowledge of Pre-Service Natural and Life Science Teachers: As Illustrated by the Case of Photosynthesis and Respiration

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**ABSTRACT** South Africa needs teachers who are scientifically literate and able to prepare learners for university so that the country can fulfill its needs for skilled people in the workplace. This study used a misconceptions questionnaire and the students' teaching journals to determine the level of content knowledge of group of nine pre-service teachers in the Western Cape. It was found that the pre-service teachers held misconceptions about photosynthesis and respiration. Some had inadequate knowledge of the content material; others were unaware of their lack of content knowledge and felt that they were well qualified to teach the subject up to the Grade 12 curriculum. Some of the implications of the findings for the training of student teachers are discussed and recommendations are offered. The latter focused largely on the need to ensure that student teaching curricula allow student teachers to be exposed to more content knowledge. Furthermore proper planning ahead of teacher practice periods is suggested and access to Learning Support Materials. This will ensure that the experience is rich and meaningful.

# 1. INTRODUCTION

Just like most countries in Africa, there are undeniably problems in the South African education system. Some of the problems include: lack of resources in schools (Bloch 2009); over-crowded classrooms (Raitt 2011; Onwu and Stoffels 2005; Phurutse 2005); interrupted lessons (Chisholm et al. 2005; Raitt 2004); and an increase in administration and record keeping (Chisholm *et al*. 2005). Teacher training does not prepare students for teaching with limited resources. The training instils an idealistic picture of teaching in students (Brouwer and Korthagen 2005), which includes many of the 'myths of teaching' listed by Breidenstein (2002).

After the first democratic elections in South Africa in 1994, education became a national imperative for change. With this in mind it is clear that the new government needed to change the education system (Manganyi 2001; Rensburg 2000; Jansen 1999). The result of this change was the introduction of an outcomes-based curriculum for South African schools (Jansen 1999; Kraak 1999). Subsequently, several curriculum changes were introduced after 1994. The Curriculum 2005 was launched in 1997 by the late National Minister of Education, Professor Sibusiso Bengu. Several curriculum reviews followed and the National Curriculum Statement (NCS) for Life Sciences (Grades 10 to 12) was ultimately streamlined in 2008. In 2010 the current National Minister of Basic Education after recommendations from the Curriculum Review Committee, introduced finally a streamlined National Curriculum and Assessment Policy document for public comments including the Life Science curriculum. This document is the official National Curriculum and Assessment Policy Statement (CAPS) for South African schools which was implemented in 2012. It is hoped that this curriculum would improve learners' science literacy. This frequent change led to a situation where change has been too rapid for both educators and learners. Schwab (1969) noted that the first requirement of the 'practical arts' was that existing institutions and practices should be preserved and changed gradually and should not be dismantled or replaced. Change must not impair the functioning of the whole education system. Changes must be incremental so that coherence is retained. Schwab (1969) advised that people need to know "which needed changes can be instituted with what

costs or economies, and how they can be effected with minimum tearing of the remaining fabric of educational effort "(Schwab 1978).
Furthermore, as Schwab (1973) observed, the learner, teacher, milieu and subject matter must have equal weight in the matter of curriculum and so it is important that teachers have knowledge of all four areas. Teachers should be able to help pupils relate what they learn in classroom to the outside world. Teachers should know the "knowledge structures characteristic of the scientific disciplines underlying their school subject" (Brouwer and Korthagen 2005) and be able to choose, organize and present this material to specific groups of learners (Brouwer and Korthagen 2005; Turner-Bisset 1999; Even and Tirosh 1995; Driver 1991; Shulman 1986). Teachers also need to know how a child learns and what children of different ages find difficult to learn (Shulman 1986). According to Shulman (1986) teachers need to be able to answer the question often asked by learners, "But why do we have to know this? Is it relevant to us?" Teachers should thus know the value of what they are teaching. They need to know what teaching programmes exist and what learning support materials are available and how effective they are (Brouwer and Korthagen 2005; Shulman 1986). Teachers need to therefore have an understanding of schools science knowledge (subject matter knowledge, Shulman 1986) both in the form of syntactic knowledge (processes by which theories and models are established as valid; Schwab (1978) as well as the substantive knowledge of their disciplines (Schwab 1978; that is, concepts, principles). This paper focuses on aspects of substantive knowledge of school Life Sciences/Natural Science knowledge.

In essence, the main research question is: *Does a select group of South African student teachers have the required content knowledge to teach Life Science effectively?*

## II LITERATURE REVIEW

### (a) Conceptualization and contextualization of science teacher education

Based on this research question, this study looked at the content knowledge of a selected group of student teachers Natural Science and Life Science teachers at the University of the Western Cape who were involved in the *Teaching Biology Project.* The selected content knowledge relate to the concepts of photosynthesis and respiration as well as food chains and food webs.

The *Teaching Biology Project* mentored pre-service Natural Science and Life Science teachers. This involved discussing of lesson plans, helping by empowering the student teachers to find resources and learner and teacher support materials (LTSM) and visiting the selective / placement schools where they are doing practice teaching. The student teachers, in turn, gave the mentors access to their teaching journals and also completed a misconceptions questionnaire.

- **STUDENT TEACHER EDUCATION**

Pre-service teachers should learn the theories of teaching and learning that form the basis of teaching and this is expected to happen at tertiary level (Burn 2007; Turner-Bisset 1999). This knowledge is decontextualised and pre-service teachers need to see how it is applied in practice. This is done during their teaching practice where they learn from teachers the "professional craft knowledge" (Burn 2007). However, Brouwer and Korthagen (2005) admonish that teachers in schools are not really role models because they tend to be conservative and deliver teacher-centred lessons and this is confirmed by Quick and Siebörger (2005) who quote a student as saying, "Most of us went with what we saw when we were in school, not what we learned at university." Breidenstein (2002) further notes that unless pre-service teachers confront the myths about teaching that they hold, what they learn in training will be "washed out". Content knowledge according to Shulman (1986) is comprised of subject matter knowledge, pedagogical content knowledge and curricular content knowledge. The knowledge of subject-matter and how it is organized for teaching form part of what Shulman (1986) refers to as pedagogical content knowledge. Other aspects of PCK include knowledge of the student (and their conceptions and misconceptions they might hold on curriculum topics), knowledge of the curriculum and its goals, knowledge of instructional materials and pedagogical practices. This paper looks at content knowledge in the general sense.

- **The teaching of science and pedagogical content knowledge to teach science**

The quality of school education is tied very closely to the quality of teacher training (Taylor et al. 2013). As a result of this countries as they respond to the changing world, change and amend and improve their curricula and schooling programmes and with it their teacher education programmes. South Africa has followed suit in this regard. The quality of science teaching is intrinsically linked to quality of teacher education programs as well as the science disciplinary preparation for teaching school science. Several studies show a positive correlation between higher student achievement and teacher performance and teacher subject matter preparation (Darling-Hammond 1999). Others find that prospective teachers do not have the depth of subject matter knowledge to respond to students questions beyond the basics (Wilson 2002).

Science teachers have to have a disciplinary background to teach science and this includes having certain skills (for example, laboratory skills), curriculum knowledge and an understanding of the nature of science. In South Africa generally science teachers follow one of two routes to becoming a qualified teacher. Generally science teachers are prepared for teaching in a four year professional B.Ed programme in South Africa. This accredits the teacher to teach up to the senior phase of schooling (grade 9). The science and education disciplinary modules are followed concurrently. FET level science teachers are prepared for teaching grades 10-12 in High School. The undergraduate disciplinary focus is a science degree for the latter and the teaching certificate follows the degree programme and is a one year programme. The difference between the two groups of teachers would be the exposure to science content knowledge, with the latter group having graduated with a degree in the science subject. However, as can be seen from this paper, it must not be assumed that this is the norm. In fact, students in PGCE have to have completed one year or two years of an undergraduate science teaching subject to qualify as a teacher of that subject at the school level.

The knowledge of science will have an impact on initial teacher understanding of science, PCK for that content knowledge, attitude toward teaching that knowledge and student achievement in the case where this teacher ends up teaching at the school level.

**(b) The Curriculum: Content knowledge and misconceptions**

- **The CAPS Life Science curriculum for grades 10-12**

The Natural Sciences Learning Area of the South African school curriculum comprises a wide range of topics – from " how stars form to how microscopically small animals live, and from the study of crystals to understanding how the climate of the earth is changing" (DoE 2002). This is a wide range of content material to understand. The content is organized into four knowledge areas: Life and Living; Energy and Change; Planet Earth and Beyond; and Matter and Materials

(DoE 2002). The range of subjects necessary for the Life Sciences is not as broad but requires considerably more depth of understanding. According to DoE (2003), Life Sciences enable learners to understand biological, physiological, environmental, technological and social processes that impact on the environment. These include food production, distribution and consumption, health promotion, conservation, sustainable living and genetic engineering)". The content of Life Sciences is also divided into four strands of knowledge which are tissues, cells and molecular studies; structures and control processes in basic life systems; environmental studies; and diversity, change and continuity. However, Schwab (1973) warns that these subject areas are wide and that more than one person with subject knowledge should be involved when curriculum development is considered.

The new Curriculum and Assessment Policy Statements (CAPS) refer to specific aims and these replace the Learning Outcomes of the NCS curriculum policy. However, the specific aims are the topics (themes) for Natural Sciences and Life Sciences (Table 1). The first specific aim / topic hinges on acquiring knowledge of natural sciences (of Natural Sciences concepts, processes, phenomena, mechanisms, principles, theories, laws, models, *etcetera*). The second theme investigates the phenomena in natural sciences. The third theme centres on appreciating and understanding of the importance and applications of Natural Sciences in society (National Department of Basic Education 2010).

**Table 1: Topics Natural and Life Sciences**

| **Topic** | **Natural Science** | **Life Science** |
|---|---|---|
| **1** | Scientific Investigations: The learner will be able to act confidently on curiosity about natural phenomena, and to investigate. | Scientific Inquiry & Problem-solving Skills: The learner is able to confidently explore and investigate phenomena relevant to Life Science by using inquiry, problem solving, critical thinking and other skills. |
| **2** | The learner will know and be able to interpret and apply scientific, technological and environmental knowledge. | The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences. |

| | | |
|---|---|---|
| **3** | The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment | The learner is able to demonstrate an understanding of the nature of science, the influences of ethics and biases in the Life Sciences, and the interrelationship of science, technology, indigenous knowledge, the environment and society. |

The specific aims and themes /topics give an indication of the skills Natural and Life Sciences student teachers should already have mastered. It follows that student teachers should master these skills before they start teaching or they should be given opportunities to demonstrate that they have mastered these skills. The topics in Table 1 are discussed in the extant misconceptions literature in connection with the subject matter or content knowledge of student teachers and practicing teachers.

- **Misconceptions and student teacher school subject matter knowledge**

The term 'misconception' refers to "students' articulations that are not scientifically accurate" (Bahar 2003). This term is used in this paper in preference to the terms 'naïve conceptions' or 'alternative conceptions', because at university level any conceptions about Life Science can no longer be termed 'naïve conceptions' since they would have encountered it in high school. According to Jordan and Duncan (2009) the central task of biology is to foster "a general understanding of the nature of science." Thus teachers must understand science practices, origin and nature of its knowledge and how to evaluate that knowledge (Shulman 1986). However, if teachers do not understand the nature of science, then they cannot help learners to understand it. It is thus essential to get some indication of the pre-service teachers' conceptual understanding of science.

## III RESEARCH METHODOLOGY

**Research design:** The study was exploratory in nature and is a case study of the selected student teachers and their conceptual knowledge ecology in the Life Sciences subject area. The study approach is therefore phenomenological.

**Sampling:** This paper is part of a bigger project on pre-service teachers of Teaching Biology Project 2010-2012. The sample for the study is nine pre-service teachers. Data from their journals with the results of their misconceptions questionnaire and the implications of the results of the study for the design of a curriculum for training teachers of Life Sciences and Natural Sciences were also used for this paper. The sampling for this research paper is described as purposive and convenient. Data were collected during the 2010, 2011 and 2012 academic years, however this paper focuses only on the 2012 cohort of B.Ed and Postgraduate Certificate in Education (PGCE) student teachers. The findings for 2010and 2011 will be published in a subsequent comparative paper. The researchers visited the classroom and asked students whether they were interested in the project and wanted to participate. We asked for 10 participants because we offered during the entire year and we had human resource and time constraints. Ten students signed up for the project and one withdrew later into the project. This paper focuses only on a thin slice of the project and not the entire project outcomes.

Participation in the Teaching Biology Project is voluntary and students involved were paid a small stipend. Many students are struggling financially and found the stipend useful. Table 1 below illustrates the academic qualifications of these pre-service teachers and the subjects they were studying.

**Table 2 Student academic qualifications and methods subjects studied**

| | DEGREE | Faculty/ Department | METHOD 1 | METHOD 2 |
|---|---|---|---|---|
| 1 | Dip Therapeutic Reflexology<br>Dip Massage Therapy | Included Anatomy & Physiology<br>(These diplomas courses are not offered at UWC) | Life Science | Life Orientation |
| 2 | BSc | Biodiversity & Conservation Biology | Life Science | Natural Science |

| | | | | |
|---|---|---|---|---|
| 3 | BEd | Education | Mathematics | Natural Science |
| 4 | BSc | Biotechnology | Life Science | Natural Science |
| 5 | BA Hons | Sport Science Administration | Natural Science | Life Orientation |
| 6 | BEd | Education | Mathematics | English |
| 7 | BSc | Medical Bioscience | Life Science | Natural Science |
| 8 | BSc | Physics | Natural Science | Physical Science |
| 9 | BSc | Biotechnology | Life Science | Natural Science |

**Data collection methods:** Even though a questionnaire was used the study was not regarded as a mixed methods study because the survey was conducted to gain a better picture of content knowledge of the student or pre-service teachers and hence the latter was the main focus or phenomenon studied. The Teaching Biology Project mentors had access to the teacher practice journals of the participating student teachers. The researchers used these journals as data source for research and to monitor whether the students' pedagogical content knowledge had developed during their teaching practice. They were also used to investigate whether the students recognised the need for more content knowledge. Following the teacher practice period, a Colloquium was organised by the Teacher Biology Project and student teachers and some of their school mentors attended. The colloquium responses were used as an additional source of information about what the students felt they needed for teaching.

**Data collection sources: The misconceptions questionnaire:** This questionnaire, being part of a larger study, was trialled and reviewed with a group of Grade 11 learners. The questionnaire was used with the pre-service teachers in order to see if they held these misconceptions. Each item consisted of a statement with which the respondents had to agree or disagree and they had to provide a reason for their answer. This had a two-fold purpose: to allow the researcher to get an insight into the student's understanding and to decrease the effect of guessing (Holtman 2000). White et al. (2005) point out that open-ended questions allow for insight into thought processes. Gaining an insight into the thought processes of learners was the purpose of the open-ended section requesting a reason for agreeing or for disagreeing with the statement given.

There were 10 statements in the questionnaire with which the pre-service teachers had to agree or disagree. Some of the statements used stated the correct concept and some stated a misconception. This was done so that the student teachers could not assume that the statement given was a misconception. The questionnaire was designed to elicit misconceptions held by students (Holtman 2000). It was kept short because as Frazer and Lawley (2000) observed a researcher should take the amount of time the respondent would be willing to spend on answering a questionnaire into account when deciding on its length. In the pilot study an 18 item test was used and this was found to be too long. Items used for the questionnaire were checked by four experts in the field of ecology for validity.

**Student journals:** The students were required to keep journals as part of their teaching practice. In this study the journals were used to gain insight into the students' awareness of what would be required of them as teachers and of their own content knowledge. Journals were copied, for research purposes, at the end of their teaching practice which lasted three months. The journal was regarded as a continuous assessment task and contributed to the final assessment.

**Student responses to the Colloquium:** At the end of the student teachers practice teaching they were asked to participate in a colloquium where their experiences were discussed. They were required to give a presentation that reflected on their teaching experience and to note what they thought the could do to improve the training of teachers as well as to identify the challenges they faced as pre-service teachers. The full feedback on the teaching practice experiences is discussed in a subsequent paper.

**Data analysis:** The reasons given for responses in the misconceptions questionnaire were analysed for misconceptions and these were then categorised. The data from the journals and the colloquium were used to support the findings of the misconceptions test. Misconceptions about photosynthesis and respiration, misconceptions about food chains and food webs and lack of content knowledge are three categories that emerged during data analysis of the questionnaire data and only the results of the photosynthesis and respiration items are discussed in this paper.

**Ethics:** Ethical clearance for the research study was granted by the University and student teachers were informed about the purpose of the research in this project and consented to the anonymous use of their information as obtained from their journals, observations of their teaching and other data obtained from them. Student teachers were informed of their right to withdraw from the study and were assured of anonymity and confidentiality.

## IV RESULTS AND DISCUSSION

The results of the misconceptions questionnaire revealed many misconceptions held by students who were a few months away from graduating as qualified teachers. Kao (2007) found that primary school teachers can be a source of learners' misconceptions so it is necessary to ensure that pre-service teachers confront their misconceptions before they are qualified as teachers. The same can be said for secondary schools teachers too.

**Table 3: Number of valid answers given by students**

| **Student** | **No. of valid reasons given (out of 10)** | **Degree** |
|---|---|---|
| 1 | 2 | Diplomas Reflexology & Massage Therapy |
| 2 | 9 | B Sc |
| 3 | 6 | Bed |
| 4 | 3 | BSc (Biotech) |
| 5 | 3 | BA Hons (Sports Admin) |
| 6 | 3 | Bed |
| 7 | 5 | BSc |
| 8 | 5 | BSc |
| 9 | 7 | BSc |

Because misconceptions hinder acquisition of new knowledge (Stamp et al. 2006) it is important to ensure that teachers do not leave university with misconceptions because they in turn might transmit them to learners. The misconceptions found are grouped into two categories: misconceptions about photosynthesis and misconceptions about respiration. An understanding of the relationship between photosynthesis and respiration is central to understanding ecology which is an important part of the Life Science curriculum. Çepne et al. (2006) state clearly that:

Even more importantly, an understanding of photosynthesis and respiration is a pre-requisite for any systematic understanding of ecology. Food chains and food web begin with photosynthesis and end in respiration. The photosynthesis and respiration play essential roles in the flow of energy through ecosystems.

From the above it is clear that both photosynthesis and respiration and also food chains and food webs focus on energy flow in ecosystems. This paper focuses on the first two concepts and a subsequent paper will focus on food webs and food chains.

## 1 Misconceptions about photosynthesis and respiration

In response to the statement "Respiration only takes place in animals; plants have photosynthesis instead of respiration" four of the nine students agreed with the statement but even those who disagreed with the incorrect statement revealed misconceptions in the reasons provided for disagreeing with it:

*Photosynthesis is different to respiration as photosynthesis is the process of using light to make energy, whereas respiration is the loss of water.* (Student 9 PGCE)

*Respiration takes place in humans and in animals. Photosynthesis uses energy to make food.* (Student 5 PGCE)

It is clear that the majority of student teachers were confusing respiration with the statement focused on gaseous exchange. The example below indicates the confusion surrounding respiration:

*Similar process but different terms used. Respiration – inhale & exhale (carry nutrients & $O_2$ to cells so the body functions optimally) & grow. Photosynthesis uses the sun to make nutrients in order to function optimally and grow.* (Student 1 PGCE)

*Respiration is the process in which $O_2$ is inhaled into the lungs in which gaseous exchange occurs, i.e. $O_2$ is absorbed into the 'animal's' system and $CO_2$ is exhaled.* (Student 8 PGCE)

Both these statements exhibit a common misconception found by Kao (2007) that lungs are necessary if respiration is to take place. The statement "The process of respiration provides plants with their energy" showed that six of the nine students disagreed. This represents 66% of the respondents. The reasons given indicated that these students were not aware that the energy in glucose or starch is not directly usable by an organism. This also indicates that student do not have the depth of knowledge to explain photosynthesis at the biochemical level (Brown and Schwartz 2009).

*Photosynthesis provides plants with their energy, which is the form of carbohydrates (or simply, starch), i.e. carbohydrates = product of photosynthesis.* (Student 8 PGCE)

Several believed that respiration did not occur in plants. The reason for this could be that when teachers and textbooks discuss respiration they do so in the context of human and animal biology (Uno 2009). It is clear from the statement below that this student is unaware that respiration occurs in plants as well as animals.

*(Respiration) provides humans with energy & circulates & delivers nutrients to cells in the human body.* (Student 1 PGCE)

Even those who were aware that respiration occurs in plants did not understand why it was necessary. In agreement to this, Lazarowitz and Lieb (2006) found in their study of undergraduate students studying the human respiratory system that students do not know that respiration produces energy. It is clear like in the study by Brown and Schwartz (2009) that students hold the misconception that only photosynthesis is an energy process. The student quoted below agreed with the statement that "the process of respiration provides plants with their energy" but offered this reason:

*Respiration gets rid of all the unnecessary substances & the useful energy rich substances are then left in plant cells.* (Student 3 BEd).

As Kao (2007) points out "respiration is a key life process" and if students do not understand it they will fail to understand how living organisms function. Mak et al. (1999) explain the problems students have in understanding concepts such as photosynthesis, respiration and transpiration in a fragmented way and this is as a result of how the material is laid out in the syllabus. The student hence cannot develop a holistic concept of water relationships in plants.

In summary, it is clear from the above that student teachers do indeed have fragmented and not a coherent integrated understanding of the complex, dynamic and connected concepts of photosynthesis and respiration. Both processes are described as having multiple ecological levels (Chi 2001). Brown and Schwartz (2009) found in their study that students held varied views of the processes, most of them saw the processes as "opposite" (Käpylä et al. 2009) could not connect the processes. They had very simplistic understandings of the two concepts and especially at the biochemical level. They mostly saw photosynthesis as using sunlight to produce food and respiration as a gaseous exchange process.

## 3 What are the implications for the training of teachers?

There are very few who would deny that there are problems in the South African education system. Teacher training does not prepare students for teaching without resources as can be seen by Student 7's comment:

*I think that UWC is doing good, it is only the schools that do not really offer a platform to student teachers to apply the knowledge they learnt … because of lack of resources* (Student 7 PGCE).

Brouwer and Korthagen (2005) warn that "the effects of teacher education on the actual practices of teachers are generally meager." If, as Bloch (2009) believes 60 to 80% of our schools are dysfunctional, should we not be training teachers to deal with the problems rather than pretending that there are no problems? The reason why teacher education has so little impact on teaching is that it is unrealistic and does not equip teachers to handle problems. Beginning teachers experience frustration, anger, and bewilderment when dumped in schools because they are not prepared (Brouwer and Korthagen 2005).

Darling-Hammond (1999) notes:

If universities would commit their substantial resources to better preparing the individuals who become elementary and secondary school teachers as well as those who teach at the college level, they could transform the nation's educational system and stimulate higher levels of academic achievement (p.28).

### 3.1 More science content in pre-service teaching courses

As Powers (2004) points out, “Where one teacher has the potential to impact the number of students taught throughout a career, a methods course has the potential to impact many future teachers and, ultimately, a far greater number of students.” So improving teachers’ knowledge would need to start with teacher training but Tomanek *et al* (2003) felt that the science in teacher training should be taught in the Science Faculty because there is a need to improve the pedagogical content knowledge of teachers. Ball and Forzani, (2010) advocate cooperation between lecturers in the subject disciplines and lecturers in Education. Whatever stance is taken, Darling-Hammond (1999 warns that “teachers need to know much more of the subject matter than they have to teach” because teacher expertise is more important than class size. It is more important than poverty, race, parent education or any other single factor (Crouch and Mabogoane 2001; Darling-Hammond 1999).

The ideal would appear to be to offer B Ed students a science course specifically designed to cover all the science content needed, including the practical work required, to teach Natural Science, however, such a course would be limiting and would be inadequate when the syllabus changed. Kramarski and Michalsky (2010) suggest that if we teach teachers to be self regulated learners when the syllabus changes they can learn the new material because they know how to learn.

One problem is that most science departments at universities are under-funded (Rybicki 2011), have heavy teaching loads (Mlambo 2010) and would find it difficult to find staff to teach a separate course dedicated to teachers. Even though a separate science course for B Ed students is not an option it is clear from the above comments that there should be more science in the B Ed course. “More science” should include exposure to laboratory work and to how to prepare for laboratory work so that student teachers are made aware of the just how difficult and time-consuming it is to prepare for doing practical work (Greene 2000).

Another problem is that lecturers in the Science Faculty are not employed because they are necessarily good teachers but because of their ability to do research. As Tomanek *et al* (2003) and Darling-Hammond (1999) agree there is a need to improve the pedagogical content knowledge of science lecturers but as Brouwer and Korthagen (2005) warn this also applies to teacher educators. “The structure of teacher education programs may indeed be counterproductive to student teacher learning, and teacher educators themselves may not display the best examples of good teaching.” Carr (1997) scathingly dismisses much of what is taught in teacher education programmes as “just the latest fashion in emperor’s new clothes…”

### 3.2 Integration of theory and practice in teaching

Several students complained, in the colloquium, that they had been taught the theories of education but not taught how to apply them. Student 6 stated, “We were taught very useful educational theory. But we were not taught to merge theory and practice.” Student 8 found herself “unable to use Piaget, Vygotsky and Feuerstein.” Tomanek et al.’s (2003) finding that there was no connection between the theory advocated and the teaching that is practiced in Education courses shows that this gap between theory and practice is common. Teachers get lectures on teaching “from professors who have not themselves ever practiced what they teach” (Darling-Hammond 1999).

### 3.3 Integrating literacy and numeracy/quantitative skills with subject content

According to the report on the Annual National Assessments of 2011, the average percentage score for literacy in Grade 3 is 35% and numeracy 28%. Grade 6 learners do not fare any better. The average score for Grade 6 is 28% for language and 30 % for mathematics (DBE 2011). If a child cannot read, that child will have difficulty learning in any subject. This means that Natural Science teachers must be prepared to integrate the teaching of reading with their teaching of science. It is unlikely that they have been taught how to integrate the teaching of reading into science teaching.

Carr (1997) complains that contemporary professional training of teachers is of a “narrow and specialized nature” and teachers are needed to create an “educated public” in order to do this teachers themselves need to be educated people. For Carr the term “educated” extends beyond knowing about the subject in which the teacher specialized. It includes being able to use literature to illustrate the subject one specialized in. The narrowing of focus to 'applied' subjects has left teachers who are trained this way poorer. Schwab (1973) warns that the learner, teacher, milieu and subject matter have equal weight in the matter of curriculum. The four elements must be co-ordinated and balanced. Pedagogical content knowledge includes much more than a narrow focus on 'applied' subjects (Ball and Forzani 2010; Shulman 1986). It includes, among other things: hearing the learners' voices, talking to parents, knowing "how to unpack it for a learner." Teachers also need an insight into "student thought processes" and how to assess student work (Ball and Forzani 2010). Carr (1997) warns that when there is a narrow focus, teachers are less able to understand "the wider social and cultural implications of education."

### 3.4 Lack of content knowledge: subject matter knowledge

The problem with Natural Science is that the Learning Area does not coincide with any of the current degrees offered at university since it requires a combination of chemistry, physics, botany, earth science, ecology, human anatomy, human physiology and zoology which leads to gaps in teacher knowledge and as Tomanek et al., (2003) note pre-service teachers are often deficient in their subject matter preparation. In this study, the students were generally aware that they had much to learn in terms of both content and teaching skill. According to Student 7 a degree in Medical Bioscience does not equip a student to teach Life Science. He had no illusions about his mastery of the content.

*At university we were taught only the methods of teaching not the content. We knew exactly how embarrassing it is to teach something that you do not know. We had to consult our mentors about which textbooks to use.* (Student 7 PGCE)

Even Student 2, who gave nine valid explanations out of ten for his choices in the misconceptions test, felt that he needed more content knowledge.

*I have learnt that I always have to revise and check my understanding of the content so that I can teach it effectively. I have learnt that it is not possible to know everything there is about your learning area. It is also possible to research something that you do not know the answer to immediately. Admitting that you do not know something is acceptable and is better than misleading learners*. (Student 2 PGCE)

The students who held the most misconceptions were the least aware of their need for content knowledge. Student 1, quoted below, associates learning with the activities of the teacher and not with the activities of the learners and was confident that she had achieved the Learning Outcomes in all her lessons.

*For example, if the lesson is based on the particular chapter, we need to cover and should be taught according to learning outcomes 1, sometimes I touch on all the critical outcomes for that (being 1, 4 and 5). I will also incorporate the developmental outcome 1, to achieve this I will teach the content, revise the content afterwards and ask them questions to gauge how much they have learnt.* (Student 1 PGCE)

Student 5 freely admitted that he did not have extensive knowledge of his subject but this did not bother him.

*Personally, I found that, even though I didn't have extensive knowledge on the subject, I could still competently teach the subject and enjoyed it while doing so.* (Student 5 PGCE)

The question then is if students do not learn the content of what they were taught at university where will they learn it? One may also ask why they do not learn the content they were taught at university. One reason that students do not learn the content is that they might not have adequate depth of content knowledge for the teaching area on entering the Postgraduate Certificate of Education (PGCE) course. In this case in Table 2 we see that both Student 1 and Student 5 had no Life Science courses in their basic degrees.

Tomanek et al. (2003) research suggests that there is little or no cooperation between Faculties of Education and Science and that leads to poor preparation of teachers. Crook (2002) traces the history of teacher education in Britain and notes that even when teacher education became part of university education other departments "regarded the education departments with suspicion" because they were thought to "be a menace to academic standards and autonomy." This lack of cooperation is a serious problem because the most important factor in improving a learner's performance at school is the qualifications of the teachers (Crouch and Mabogoane 2001; Darling-Hammond 1999). This element is outside of the scope of the paper. It is followed up in a subsequent article.

## V. CONCLUSIONS

We conclude that student teachers do not have appropriate content knowledge to teach NS and LS curricula. Furthermore, they hold serious misconceptions about the selected concepts of photosynthesis, respiration, food chains and food webs. One issue pertinent to this is that they report that not enough resources and Learning Support Materials are available to support them during their teacher practice at schools and they are not always able to apply their theoretical knowledge at under resourced schools. It was clear from the findings that the student teachers generally were not able to fully understand the expectations of the curriculum. As Powers (2004) points out, “Where one teacher has the potential to impact the number of students taught throughout a career, a methods course has the potential to impact many future teachers and, ultimately, a far greater number of students.” So improving teachers’ knowledge needs to start with the teacher training.

## VI. LIMITATIONS AND RECOMMENDATIONS

The case study focused on the views and inputs of only nine student teachers but the population itself was also not more than 40 students. The project could only fund the participation of 10 students and therefore the convenient sampling was a result of resources. They were enrolled for the Methods of Natural Science and Methods of Life Sciences courses and hence generalisation beyond this group and case are not intended. A larger study across different disciplines is suggested to see whether this phenomenon is unique to the subject areas covered in this paper. Perhaps results would differ if the project ran over a period of more than just eight months and the teaching practise period.

The literature does point to the need to upgrade teacher content knowledge, but this project has shown us that even student teachers should be exposed to more content knowledge during methods classes. The pre-service curriculum should be realigned so that student teachers do leave with the appropriate content knowledge to teach school Natural and Life Science curricula. Student teachers struggle during the teacher practise period to find Learning Support Materials and other resources. It is often difficult to get a pre-practise teaching session with the mentor teacher at the school to plan ahead. We suggest that Universities survey their student teachers during and after their teacher practise periods to understand the real needs and to intervene ahead of the period with mentor teachers to ensure proper planning takes place. This would make the teacher practise period a richer experiential and academic experience.

Finally, Universities and schools should ensure that student teachers fully understand the expectations of the CAPS curriculum policy and learn how to stay abreast of curricula changes.

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