 Int J Edu Sci, 4(2): 107-115 (2012)

Student Teachers' Presentations of Science Lessons in South African Primary Schools: Ideal and Practice

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KEYWORDS Science Teachers. Portfolio. Subject Matter Knowledge. Pedagogical Content Knowledge. Primary School

ABSTRACT A recurring theme in science teaching in South Africa has been poor learner performance in science subjects. The article reports on an inquiry into the quality of science teaching in South African primary schools. Ideal science teaching and learning practices as presented in the literature were reviewed. Against this background, the practice of science teaching in primary schools was investigated by means of an empirical inquiry. Qualitative data were gathered by document analysis of portfolios of student teachers enrolled for a postgraduate certificate in education through distance education. The findings indicated that participants did not apply the science curriculum as intended; teaching strategies were ineffective; learner assessment followed traditional methods; and time management and lesson planning skills required further development. Generally, participants failed to implement pedagogical knowledge presented in the teacher education programme. Recommendations as to how to close the gap between ideal school science teaching and actual practice are made.

INTRODUCTION

The main aim of teaching science is to promote scientific literacy. Yet this aim is not adequately realised in many education systems even in developed countries (Nelson 1999:3; Dekkers and De Laeter 1997; Dobson and Calderon 1999; FASTS 2002; Fullarton et al. 2003; Tytler 2007). A recurring theme in science teaching in South Africa is the poor performance of learners in science subjects. The National Learner Assessment Programme revealed that Grade 6 learners' performance in science was extremely disappointing (DoE 2005). South Africa was ranked very low in the 1993, 1998/9, 2003 and 2007 Trends in International Mathematics and Science Study (TIMMS), coming last even behind other African countries that spend far less of their budgets on education than South Africa. Various factors lead to poor performance in science subjects in South Africa: excessive emphasis on curriculum changes at the expense of more fundamental issues (Naidoo and Lewin 1998); the teaching of science by non-specialist teachers; and the quality of science teachers produced by institutions of teacher education. The poor training of teachers has been highlighted by the Report of the Task Team for the Review of the Implementation of the National Curriculum Statement (DoE 2009). It is essential that government continue to support innovative methods of teaching science and provide the teacher professional development necessary to transform their practices (Osborne and Dillon 2008:22). Moreover, institutions of teacher education should continuously review their programmes of science education to ensure that they produce science teachers of excellence.

In this article the researcher examines the ideal and practice in science teaching in South African primary schools by exploring the lessons planned and presented by student teachers enrolled for science education through open and distance education at the University of South Africa (Unisa), currently the largest provider of teacher education in the country (Centre for Education Policy Development [CEPD] 2007:9). A literature study was used to examine the aim of science teaching and components of teacher knowledge and pedagogical content knowledge. This provided conceptual framework for a qualitative inquiry using document analysis as data gathering tool.

Conceptual Framework

Goodrum et al. (2001) in their review of the status and quality of science teaching in Australia recommended that the primary purpose of science education in the compulsory years of schooling should be to develop scientific literacy. They found that science is "part of everyday life and an understanding and appreciation of science concepts and processes is required by all members of society if they are to be active citizens making informed decisions and contributions to debate about relevant issues and events" (Goodrum et al. 2001:31). Similarly, in South Africa, the NCS document prescribes that the main purpose of science education during the compulsory years of schooling is scientific literacy. Scientific literacy includes an individual's use of scientific knowledge to identify questions, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues (OECD 2002:12).

The teacher plays a vital role in ensuring that the purpose of science is achieved. Shulman (1986) categorises teacher's knowledge into three, namely, subject matter knowledge (SMK), pedagogical content knowledge (PCK) and curricular knowledge. The subject matter knowledge includes the "amount and organization of the knowledge per se in the mind of the teacher" (Shulman 1986:9). His PCK consist of the most powerful analogies, illustrations, explanations and demonstrations, the ways of representing the subject matter to others in a comprehensible manner, and being able to have an understanding of what makes learning of specific topics easy or difficult to others (Shulman 1986:9). PCK refers to how teachers teach their subject by assessing what they know about the subject, the learners they are teaching, the curriculum with which they are working and what they believe constitutes good teaching in their context (Rollnick et al. 2008). Geddis and Wood (1997) reiterate that PCK includes the learner's prior concepts, subject matter representations, instructional strategies, curriculum materials and curricular saliency. PCK cannot be confined to the interrelatedness between the subject matter and pedagogy. Different forms of teacher knowledge contribute to the development of science PCK, for example, knowledge of students, classroom management, assessment, curriculum context, the environment, the socio-cultural context, and the nature of science (Appleton 2002:394). The boundaries between SMK and PCK are blurred and only students who have multiple representations for science ideas and whose science knowledge is already richly linked will be able to draw the distinction between the two. Finally, Shulman's notion of curricular knowledge includes knowledge of the scope and sequence of the teaching programmes and the materials used in them. Shulman (1986, 1987) first noted the link between teachers' knowledge and practice. Mugnusson et al. (1999) reiterate that the development of PCK is determined by the content to be taught, the context in which the content is taught, and the way the teacher makes sense of his/her teaching experiences. Reflection on practice, emerges as another important aspect for student teachers in developing expertise in their practice, and is also central to them accepting more responsibilities for their actions (Loughran 2002). The articulation of links between practice and knowledge has proved to be exceptionally difficult because, for many teachers, practice and the knowledge that tends to influence that practice are often tacit (Schön 1983).

The articulation of the links becomes even more complex in open and distance learning (ODL) institutions such as the University of South Africa (Unisa). Student science teachers in an ODL context are faced with the challenge of ensuring that the primary aim of science is achievable; of bridging the gap between the actual and the ideal, the theoretical and the practical; and of blending pedagogy with subject matter knowledge.

RESEARCH DESIGN AND METHODOLOGY

Against this background, the following research question was formulated: How effective is the presentation of natural science lessons in South African primary schools made by student teachers enrolled in teacher training through distance learning? The study was located within a qualitative paradigm aimed at a detailed understanding of classroom practices of student teachers enrolled for science education with a view to informing teacher educators and teacher mentors about gaps in student teacher knowledge.

Sampling

Two entry routes to a professional teaching qualification exist at Unisa: the four-year Bachelor of Education (BEd) degree programme and, for those already in possession of an appropriate degree, the one-year Post Graduate Certificate of Education (PGCE). Students interested in teaching science are required to enrol for the module: Learning Area Didactics: Teaching of Natural Sciences (subject code LADNSCC) offered as part of both the BEd and the PGCE programmes (Unisa 2010a). The module deals with the methodology of teaching natural sciences in the intermediate and senior phases (Grades 4–9) of the General Education and Training Band (GET) (DoE 2003). LADNSCC elaborates on teaching strategies, namely, co-operative learning strategies, process skills and the learning cycle, scientific literacy, assessment and scientific inquiry. In conjunction with LADNSCC, six compulsory themes (from a possible eight) are intended to equip students for the profession.

In 2009, 258 students enrolled for LADNSCC. As part of continuous assessment, they submitted a teacher portfolio which set out lesson plans for a series of four science lessons, which were subsequently presented in the presence of a mentor teacher. A teacher portfolio is a document created by a student teacher that describes his/her duties, expertise and growth in teaching and includes a purposeful collection of examples of work gathered over a period of time (Smith and Tillema 1998). In this study, 40 portfolios (N = 40) were selected from the total population of 258 students according to a simple mathematical random sampling procedure (Neuman 2007:227). Most of the sampled portfolios were from students enrolled for the PGCE; a small number were from students enrolled for the BEd.

Data Collection

Portfolios were used as the primary source of data gathering, as they gave an account of actual practice, that is, the detailed steps followed by the student teacher in the presentation of a science lesson in a classroom (Campbell et al. 1997). Document analysis can be defined as the systematic examination of instructional documents such as syllabi, assignments, journals, and course evaluation with the aim of identifying instructional needs and challenges and/or obtaining a description of an instructional activity. In the case of this study, each LADNSCC portfolio contained four lesson plans. Each lesson plan comprised a class description: time, grade (Grades 4–9) and lesson content, learning outcomes, teaching media, prior knowledge of learners, introduction, new knowledge, teaching strategies, resources to be used, teacher and learner activities, assessment and reflective self-assessment. To evaluate each lesson, lecturers teaching the LADNSCC module employ specific criteria, including the link with prior knowledge, teaching strategy employed and the form of assessment. A section in the portfolio is also allotted for critical appraisal of the lessons by mentor teachers at the school at which the lessons are presented and these comments were also used in the data analysis.

Data Analysis

Creswell (2007) and Marshall and Rossman (2006) recommend that data analysis in a qualitative investigation should occur using multiple levels of abstraction. The analysis should move from the particular to the general, taking into consideration multiple themes and alternative explanations. The method of analysis followed for the examination of the student portfolios included familiarisation, immersion, coding and formulating themes. The 40 portfolios were examined for indicators of categories such as: how the learning outcomes for the lesson were articulated; which teaching methods were used; how these were applied; learner assessment techniques used to assess learners; and the written comments by teacher mentors to realise and improve the student teacher's professional development. Different categories were named and coded, and codes were compared to find consistencies and differences (Miles and Huberman 1994). Consistencies between codes indicated a basic idea or theme. A category was considered saturated when no new codes relating to it were formed. Certain categories, in this case, the school science curriculum, teaching strategies, learner assessment as related to the intermediate and senior phase and professional teacher development, became core categories or themes. In addition, certain sub-themes were identified which lent additional richness to the core categories. The themes were compared with the literature for further clarification.

RESEARCH FINDINGS AND DISCUSSION

According to Green and Thorogood (2004), qualitative findings are presented by describing themes substantiated and enriched by quotes or raw data from the interviews. In this article I follow this mode of presentation, and themes and sub-themes are presented as rich data, substantiated by means of relevant quotations from the teacher portfolios.

School Science Curriculum

Discussion of the themes and sub-themes is presented in the sections that follow.

Reaching Science Learning Outcomes (LOs)

The three learning outcomes in the natural sciences GET band (DoE 2003) are as follows: Learning outcome (LO) 1: Scientific investigations; Learning outcome (LO) 2: Constructing science knowledge; Learning outcome (LO) 3: Science society and environment. The learning outcomes form a framework from which science content should be drawn. The curriculum framework has a structure for content that is prescriptive; nevertheless a teacher has considerable freedom to structure a lesson and present it in a way relevant to the learners.

The findings indicated that the interpretation and application of the three learning outcomes was problematic. Student teachers concentrated more on content than on the outcomes and frequently outcomes were not linked to improvements to learners' existing knowledge as exemplified by a Grade 9 lesson: "Acids and bases," which stated LO1 as the lesson outcome. The lesson plan revealed that the student teacher was in fact engaged with another learning outcome. According to the stated outcome, learners were expected to conduct an investigation into acids and bases. Yet in the presentation, "learners were expected to categorise acids and bases". The latter fell under LO2. Where more than one learning outcome was used, most student teachers did not link the outcomes. In a Grade 8 lesson, a student teacher stated that all three learning outcomes were applicable. The main part of the lesson stated:

Learners do a survey of electrical consumption in their homes. They find out which appliances are left operating throughout and which ones are operating periodically. I will explain on how learners can collect the information from different homes.

This lesson should have been comprehensive, since three learning outcomes were to be achieved. The student teacher did not show categorisation of information relating to electricity and gave no indication of how to reduce complexity with regard to defining the concept "electricity". Moreover, no effort was made to achieve LO3; there was no reference to or link with technology and the broader environment as electricity is not confined purely to household use.

Finally, most student teachers found it difficult to link LOs with the content. This caused a mismatch between the student teachers' actual classroom practice and their stated intentions with the lesson. They tended to ignore what they were supposed to achieve at the end of the lesson and immersed themselves in content instead. Student teachers were unable to transform the learning outcomes into practice.

Activation of Prior Knowledge by Linking With Learners' Everyday Experiences

Student teachers struggled with the activation and application of learners' prior knowledge. They were unable to state clearly how they planned to elicit learners' prior knowledge before introducing a new concept. Many student teachers indicated that they would ask questions. Only questions that link prior knowledge with new knowledge should be regarded as useful. Preparatory activities involved questions formulated in terms of jargon or written exercises:

Learners will be asked some oral questions on the introductory part of the topic (enzymes) to find out if they have an idea on the topic, and how much of it they know.

Learners will be given a short exercise to write about the topic and this will be marked on the spot, to find out how much learners know, and where they may not be strong.

Science is an activity in which those who conduct it get improved through a combination of instruction and practice. Questioning as indicated in the lesson presentations were poorly planned and haphazardly posed which would not lead to activation of prior knowledge.

In a Grade 9 lesson plan: "The microscope," the student teacher indicated that no prior knowledge existed for that lesson "as this is a new section, all knowledge will be new." However, the concept could easily have been linked to everyday knowledge, such as wearing spectacles to correct problems of sight or the use of a magnifying glass to read small print. Student teachers failed to use concrete examples familiar to learners to draw out prior knowledge. Learning only takes place when a new concept "ties in" with the prior knowledge and the new information expands existing knowledge. The effects of prior knowledge require a change from the view that learning is absorption of transmitted knowledge to the view that learning comprises conceptual change (Champagne et al. 1985). Ausubel (1968: IV) states that "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him [or her] accordingly". Teachers must learn how to guide their learners in sequencing assignments aimed at using everyday knowledge as a means to absorb and "own" academic concepts (Ausubel 1968:262). These principles were not demonstrated in the student portfolios.

Relevance of the Curriculum to the Needs of Learners

According to LO3, learners must demonstrate an understanding of the interrelationships between science and technology, society and the environment (DoE 2003:3). Thus, any science lesson should make connections with learners' needs and experiences. Student teachers did not clearly show the link between the subject knowledge and everyday life as demonstrated by the item "teaching media" in the students' lesson plans. Teaching media that were fairly easy to come by, such as newspaper clippings, video clips, artefacts, models and diagrams, were often absent. In none of the portfolios perused was mention made of linking a lesson with visits to a museum, zoo, factory or artisan's workshop. No visits by a local nurse or medical practitioner to address learners on a topical issue such as HIV/AIDS were suggested. Instead, student teachers preferred to use textbooks and chalkboards. Alarmingly, student teachers enrolled for a well-designed course such as LADNSCC appeared not to have assimilated ideas about teaching aids that could be improvised even in impoverished areas. In a Grade 9 lesson: "Acids and bases", the only teaching media used were textbook and chalkboard. Common household substances, such as lemon juice, vinegar, baking powder and bath soap, which could have been used to differentiate between acids and bases, were ignored. The student teacher justified himself/herself by commenting: "because of lack of educational resources, I could not show the learners how acids reacted with other substances, e.g. metals and metal oxides."

Teaching Strategies in the Science Lesson

Cooperative Learning

Slavin (1983) defines the cooperative learning process as a set of alternatives to traditional instruction systems or techniques in which learners work in heterogeneous groups of four to six members, earn recognition and rewards, and are sometimes graded based on the academic performance of their groups. There are in essence two features that distinguish cooperative learning from other forms of small-group instruction: positive interdependence and individual accountability. In most lesson plans, student teachers acknowledged the usefulness of cooperative learning as illustrated:

Cooperative learning, problem solving and classroom discussions work well in science classes. Learners remember more and are able to apply themselves better when they are actively involved.

However, in most cases student teachers regarded cooperative learning as synonymous with group work (Kagan 1994; Slavin 1983). They placed learners into groups, but nevertheless used traditional teaching strategies (direct questioning, teacher-made summaries and textbooks) as shown by the following:

I divided the class into groups of three learners each. I asked learners questions and also answered their questions. [I] copied the summary of the lesson on the board. [I] provided learners with resources e.g. textbooks.

Traditional ways of teaching remained the order of the day as long as learners were in groups as illustrated:

I explained to learners how to prepare and test for oxygen, carbon dioxide and hydrogen. I carried out experiments for the preparation and test for oxygen, hydrogen and carbon dioxide. Learners observed attentively as I demonstrated the preparation and test for these gases.

In this case, the student teacher thought he/she was performing an experiment, even though positive interdependence, face-to-face interaction, individual accountability, personal responsibility and team work spirit were absent. This shows the confusion that creeps in between the practical implementation of cooperative learning and its theory.

Further, there was little evidence that the student teacher monitored interdependence or individual accountability: he/she was satisfied merely to hear learners discussing or talking to one another in groups. The instruction to form groups was given without setting any structured cooperative learning task which required teamwork to accomplish a common goal. In contrast, a well-structured cooperative learning task will result in learner participation, motivation and enhancement of thinking skills, which are the integral components of the aim of science teaching, namely scientific literacy.

Further, the teacher's role remains crucial in cooperative learning. Teachers must consider different learning skills, cultural background, personality, and even gender when arranging cooperative groups. Time should be devoted to preparing a lesson for cooperative learning, during which the teacher should act as a coach or facilitator. The teacher cannot leave the process of learning to unfold on its own. In the striking anecdote below, a student teacher described his/her abdication of leadership, which created a situation where learners were left rudderless. Yet, he/she regarded this as an acceptable teaching strategy.

In this lesson (human digestive system), I used a laissez faire style where I let things happen without leadership and learners follow their own ideas, deciding what the right answer is.

The laissez-faire approach is problematic because the teacher is responsible for ensuring that materials for the lesson are available to learners and that learners work more effectively in well-organised classrooms.

Inquiry Learning

Learners' practical work should focus on scientific inquiry which takes place in an activity in which a learner uses thinking skills and processes, such as formulating questions and hypotheses, predicting, interpreting data, synthesising information, and drawing conclusions (Chin and Kayalvizhi 2002). Learners are expected to observe scientifically, linking observations with scientific knowledge. Learners are not only expected to master process skills; the teacher should also ensure that learners combine scientific processes with scientific knowledge, with the intention of creating a space for learners to communicate and formulate scientific arguments.

Portfolios showed that student teachers tended merely to equate practical lessons with inquiry learning. However, experiments can be conducted without guiding learners to scientific thinking. Students also regarded demonstration as a scientific inquiry activity. In a Grade 9 lesson: "Chemical reactions", it was stated:

Learners will watch practical demonstration and take note of results – evaluate results, draw conclusions, complete assessment activities. Read passage on limestone rock and answer self-assessment exercise. Research the extraction of iron from ore with a partner.

In essence the student teacher carried out a demonstration lesson on the decomposition of copper carbonate. Learners were expected to observe the lesson, take notes and complete an assessment worksheet. This cannot be equated with learners' performing an independent experiment. Only when learners conduct activities themselves are they effectively involved in scientific thinking, which differs from mere observation. Lack of inquiry learning in science classes retards learner capacity for and skills in analysis, problem solving and the communication of ideas.

Learner Assessment Techniques

Assessment is an essential tool in the teaching-learning environment, as it determines what learners learn, what is taught, and how it is taught (Dreyer 2008:5). The result may be used to improve subsequent learning. Analyses of student teacher portfolios indicated limited and conventional use of assessment tools or techniques, namely, homework, tests and oral questions. Assessment techniques, such as portfolios, quizzes, projects, self-assessment, peer assessment, group assessment or oral presentation did not form part of assessment methods. Student teachers tended to use old assessment tools/methods, viewed as authentic. Summative assessment dominated the assessment processes in most of the lessons student teachers presented at schools. In one instance, a student teacher stated:

As a form of assessment, learners will be asked oral questions. They are expected to la-

bel a flower, and state functions of different parts, and define types of reproduction. This will be expected to be done in writing, and it would also include the definition of pollination, agents of pollination, and a table comparing insect wind pollinated flowers.

In this case different assessment methods could have been used: learners could have been asked to collect and press flower specimens from the garden or veld as part of an assignment. More exciting techniques linked to everyday experiences could have been used. Moreover, student teachers placed more emphasis on written work than on practical assessment; assessment was predominantly content based.

In a Grade 8 lesson: "Sexually transmitted diseases" written assessment using true or false responses was used. Given the HIV/AIDS pandemic and the related publicity in even the most disadvantaged communities, assignments requiring learners to collect posters from the local clinic on HIV and AIDS prevention, its relationship to TB and the collection of recent statistics or newspaper reports would have been easy to implement. Moreover, the assessment should have also linked with the learners' experiences. Finally, feedback is vital to assessment and must form an integral part of assessment process. In the section on assessment in the lessons plans, no one mentioned how he/she intended giving learners' feedback. Moreover, none of the 40 portfolios mentioned giving feedback to parents.

Professional Teacher Development through the Contribution of Mentor Teachers

Mentor teachers are appointed by Unisa at each school with the task of guiding and supporting student teachers during their teaching practice periods; assisting the student teacher with the acquisition and refinement of knowledge, skills and abilities; providing support and constructive feedback, the opportunity to reflect on own performance; creating conditions for professional growth; and, together with the principal, providing the university with an authentic assessment report for the benefit of the student (Unisa 2010b). Mentor teachers are expected to follow up on an observed weakness over a series of at least four lessons.

In their written comments, mentor teachers pointed out weaknesses in the student teachers' presentation of the lesson described in the lesson plan. Mentor comments frequently indicated a problem with time management. One mentor commented:

The lesson (chemical reactions – decomposition of compounds) was slightly longer than the allocated lesson time. The self-assessment activity that was to be completed in class was given as an additional enrichment exercise together with research activity. The lesson was successful but you need to improve with regard to time management.

Mentors also raised concerns about the efficient use of learning support materials which are an integral part of the science curriculum. Although learning support materials cannot replace the science teacher, successful learning depends greatly on the teacher's ability to identify the relevant resources, then design, adapt or use them to produce effective learning support materials. Commenting on a lesson presented on "Energy and Change", a mentor teacher stated:

The level of science literature used by the teacher is quite good, however,... teaching and learning support materials should be prepared thoroughly in advance to enhance maximum usage.

Mentors noted that learning support material was not prepared ahead of time by student teachers, which is essential to a successful experiment or demonstration implying that student teachers arrived at science classes unprepared. A mentor commented:

There are so many biological/scientific terms involved in this topic (excretion) and these are intricately linked, so the teacher needed to plan carefully so that the learners have a full understanding of these and their relation to other topics.

Another mentor teacher said the following about the preparation of a lesson:

Not a good idea to teach the concept (electrostatic) while the learners are doing the experiment – they were not listening at all. Group/experimental work was not controlled enough. Try to make the groups more structured and then there will be fewer disturbances.

A lack of prior lesson planning was particularly striking in the performance of experiments. Science teachers should do a trial experiment before performing it in the class.

Apparatus/chemical constraints have disturbed learner involvement. A way around this *might be to organise small group "shifts" to do the practical component, while the other learners complete a worksheet. The lesson given was nevertheless, a sound learning experience.*

A challenge facing science teachers, especially in rural areas, is finding appropriate teaching resources. Mentor teachers felt strongly that student teachers should improvise suitable resources for science teaching. Where complicated and expensive laboratory apparatus and, in some instances, chemicals are not available, simple household apparatus and substances used in the kitchen could be used. Mentors emphasised:

To sustain interest of learners and full integration of theoretical and practical concepts, in science, it calls for serious innovations on the teacher's approach. More audio, visual aids need to be introduced in the lessons. Where they are not available, teachers should learn to improvise.

The findings discussed above suggest serious shortcomings in the knowledge and skills of student teachers enrolled for a science module at Unisa in a distance learning context. Conclusion and recommendations are presented in the following section.

CONCLUSION

The findings suggest gaps between what science teachers are expected to do in the classroom and what they are actually doing. Although student teachers take six compulsory modules in their programme, they failed to utilise pedagogical content introduced elsewhere in the programme in their science teaching and appeared unable to transfer the pedagogical knowledge presented in these other themes to their science teaching. They struggled with basic pedagogical practices such as time management, learner organisation and lesson planning which they should have mastered in order to teach, not only a science class. In general the findings suggest that LADNSCC is unsuccessful in producing quality science teachers among the sample studied. However, it is not possible to generalise on the basis of the sample used in this study; this calls for a more comprehensive examination of the population (all science students) in a further study. If science teachers are not properly trained by teacher education institutions, the future of those learners taking science subjects at school level will remain dismal.

RECOMMENDATIONS

It is imperative that institutions of higher learning use teaching methodologies which promote and assess deep student learning. Student teachers should be taught how to design laboratory experiences with clear learning outcomes in mind. Science modules offered at institutions of higher learning should instruct student teachers how to translate science knowledge into meaningful science lessons.

Research findings show that learning proceeds primarily from prior knowledge and only secondarily from the presented materials. If prior knowledge is at odds with the presented material, learners will consequently distort the presented material. Student teachers need to understand, through the modules that are offered at institutions of learning, how prior knowledge affects learning. Science as a constructive activity draws upon everyday knowledge. Therefore the notion that scientific knowledge should not appear different from everyday knowledge, both in its form and content, should be stressed.

Student teachers need support and practice in applying what they have already learnt in science modules. Technology should be incorporated into science instruction. Science modules should incorporate new technological strategies and tools on how to teach science. Practical work should be regarded by teacher educators as an integral part of science modules.

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