SCIENCE TEACHER EDUCATORS' ENGAGEMENT WITH PEDAGOGICAL CONTENT KNOWLEDGE AND SCIENTIFIC INQUIRY IN PREDOMINANTLY PAPER-BASED DISTANCE LEARNING PROGRAMS

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ABSTRACT

This article focuses on the dilemmas science educators face when having to introduce Pedagogical Content Knowledge (PCK) to science student teachers in a predominantly paper-based distance learning environment. It draws on the premise that science education is bound by the Nature of Science (NOS), and by the Nature of Scientific Inquiry (NOSI). Furthermore, science educators' own PCK, and the limitations of a predominantly paper-based distance education (DE) model of delivery are challenges that they have to face when introducing PCK and authentic inquiry-based learning experiences. It deprives them and their students from optimal engagement in a science-oriented community of practice, and leaves little opportunity to establish flourishing communities of inquiry. This study carried out a contextual analysis of the tutorial material to assess the PCK that the student teachers had been exposed to. This comprised the ideas of a community of inquiry, a community of science, the conceptualization of PCK, scientific inquiry, and the 5E Instructional Model of the Biological Sciences Curriculum Study. The analysis confirmed that the lecturers had a good understanding of NOS, NOSI and science process skills, but found it difficult to design interventions to optimize the PCK development of students through communities of inquiry. Paper-based tutorials are ideal to share theory, policies and practices, but fail to monitor the engagement of learners in communities of inquiry. The article concludes with a number of suggestions to address the apparent lack of impact power of the paper-based mode of delivery, specifically in relation to inquiry-based teaching and learning (IBTL).

Keywords: **Pedagogical content knowledge, nature of science, nature of scientific inquiry, community of inquiry, inquiry-based teaching and learning.**

INTRODUCTION

A predicament that science teacher educators face in Distance Education (DE) lies rooted in the operationalization of the Nature of Science (NOS), the accompanying science process skills, and the design of teaching interventions through communities of inquiry. This is important as it ensures that the outcomes of science teacher education programs are met in terms of scientific inquiry. The first purpose of this article is to address some of the dilemmas in introducing PCK to student teachers, and regarding the inclusive, inquiry-based teaching and learning (IBTL) strategies used at a mega-DE institution (Hulsmann & Shabalala, 2016). Secondly, the focus also falls on the development of strategies that could combine and integrate university infrastructures, which would expand the developing PCK of student teachers. Thirdly, the evidence drawn from the case study also addresses the primary research question: How do science teacher educators engage with PCK and scientific inquiry (SI) in predominantly paper-based distance learning programs?

Furthermore I found it puzzling that, regardless of the availability of supportive infrastructures and resources, DE practitioners still find it difficult to move away from inadequate second and third generation DE modes of delivery to a more demanding fifth generation approach. Are our decisions governed by restrictions within DE modes of delivery or by our own fragile Pedagogical Content Knowledge (PCK)?

In the first part of the article, I will discuss the concepts of Nature of Science (NOS), Nature of Scientific Inquiry (NOSI), PCK, as well as science teaching in terms of the literature. I will then further relate these to teacher education in general, the main purpose being the extraction of common denominators related to NOS, NOSI and BSCS 5E principles. A discussion of the 'Community of Inquiry' elucidated by Garrison (2007), and Garrison and Arbaugh (2007) will follow, while the Biological Sciences Curriculum Study (BSCS) 5E Model of Instruction (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook & Landes, 2006), which has for some time dominated as a strategy and approach towards inquiry-based science education, will be explained. Part two reports on the content (textual) analysis of the tutorial material (Byrne, 2001; Cohen, Manion & Morrison, 2000; Maree, 2016). This allows for an exploration of the articulation and operationalization of NOS, NOSI, PCK and science processes and skills in the paper-based tutorial material, and also highlights the difficulty that paper-based models have in creating functional communities of inquiry. The final section presents a critical dialogue that proposes instructional intervention in the form of creating communities of inquiry through blended, converging modes of delivery.

BACKGROUND TO THE STUDY AND PROBLEM STATEMENT

The Department of Mathematics and Technology Education in the Faculty where the study was conducted, follows mainly a second and third generation mode of delivery, serving students with various levels of access to online facilities. The majority of the students at this institute are practicing teachers who are upgrading their qualifications. Online options include a university portal replacing face-to-face contact sessions, which were abandoned a few years ago. Student teachers who are enrolled for specific programs now receive tutorial material consisting of module Study Guides (SG) and accompanying Tutorial Letters (TL). The SG usually contains valuable information regarding the substantial component of the module, while the TL covers the syntactical procedures that form part of the structure of the different subjects taught by the methodology lecturers. Study guides are kept in circulation for seven years, and tutorial letters are updated annually. Lecturing staff are often not the designers of the programs.

The past decade has seen the emergence of two aspects related to the teaching of science, which not only impact the way in which science is being taught, but also the way that new information (and especially indigenous knowledge) can be retrieved from participants. The first of these is the popularity that IBTL has gained as a teaching strategy over the years (Minner, Levy & Century, 2010) and the apparent reluctance of instructional designers to accommodate this strategy in DE programs. Minner, Levy and Century (2010, p. 474) emphasize the importance of this by claiming that, "Teaching strategies that actively engage students in the learning process through scientific investigations are more likely to increase conceptual understanding than are strategies that rely on more passive techniques."

The second aspect is complicated by the fact that the DE landscape, with specific reference to paper-based modes of delivery, does not encourage the engagement of student teachers in communities of inquiry. There is evidence that paper-based tutorials can only engage learners in a single direction, allowing them to follow one path only (Poulton, Conradi, Kavia, Round, & Hilton, 2009). This therefore restricts them in engaging in activities where peer-support and peer feedback are paramount to professional development. The same applies to participating in action research data collection strategies and interventions, such as Participatory Reflection and Action (PRA). In these strategies, participants are given the opportunity to disseminate information in groups during data collection activities

(Chambers, 1994a; Chambers, 1994b; Ferreira, 2008; Fraser, Ferreira, Kazeni, Beukes & Eberlein, 2015; Von Maltzahn & Van der Riet, 2006). PRA has a dual purpose: it has strong emancipatory and empowering features, and allows educators to gain insight into the benefits of newly-acquired methods and strategies of teaching. Furthermore, third-generation DE models have the capacity to actively engage student teachers in aspects of inquiry (Adewara & Lawal, 2015; Perry & Edwards, 2005), yet with the exception of individual lecturers who involve their student in IBTL, the majority still fail to do so. Why, regardless of the availability of supportive infrastructures and resources, does it appear that science educators working in DE still find it difficult to engage their student teachers in activities that will develop their IBTL strategies and emerging PCK accordingly? Secondly, why do existing infrastructures fail to expose student teachers to the essence of PCK and IBTL?

At this institution, a decision was made more than ten years ago to do away with annual contact sessions (discussion classes) mainly because of the high maintenance cost, and the limited impact they had on throughput and retention. It is estimated that approximately only 15% of enrolments benefitted from the contact sessions (Personal communication, DE specialist and consultant, and Van Zyl, Spamer & Els, 2012).

RESEARCH QUESTIONS

The aim of this study was to explore how science educators engage with PCK and scientific inquiry (SI) in paper-based Distance Education programs. The study addressed the following primary and secondary research questions:

- **How do science teacher educators engage with PCK and scientific inquiry (SI) in predominantly paper-based distance learning programs?**

Supplemental to the main research question the following secondary research question contributed to address the outcomes envisaged with the primary research question:

- **How do science methodology lecturers working in a DE environment accommodate NOS, NOSI, PCK and science process skills in their tutorial material?**

CONCEPTUAL FRAMEWORK OF THE STUDY

For the purpose of the study, I decided to use Engestrom's Activity Theory (Engestrom, 2000) as the theoretical and conceptual reference of the investigation. Each of the components of Engestrom's Theory capture the details of the DE landscape as a community of practice (Wenger, 1998) as follows: The 'subjects' of the study were all DE practitioners (teaching staff, distance education experts, managers and instructional designers) who functioned within the context of DE. Interestingly enough, Hodson (2009) also regards science as a community of practice and "community-directed activity" (p. 89). The practitioners mentioned earlier all worked within certain guidelines or 'rules' that describe our methodological, ethical, normative functions and copy right requirements, for example, qualitative research and scientific inquiry depend on certain protocols or rules to be followed. Hodson's (2009:78) model for teaching and learning about science, his reference to scientific methods and processes, the 5E Instructional Model of Bybee et al. (2006) and the NOSI embraced by Lederman et al. (2014) build on the rules, tools and roles outlined by Engestrom's framework. They qualify the methods we should follow and the ethical standards that we have to meet. The researcher functions within this specific research community where one has to engage with peers, critical friends, and experts to achieve certain outcomes. The same applies to DE as a teacher education landscape and serving community of practice. Different roles and functions are therefore performed and labor is divided into teaching, management, and research, amongst others.

RESEARCH METHODOLOGY

I have been working as Life Sciences methodologist for close to 30 years and focused mainly on the teaching of scientific inquiry and the science process skills since 1986. My knowledge and experience of curriculum design and development brought be closer to program evaluation, content analysis and narrative inquiry, which would explain why in this study, a hermeneutic textual analysis (Byrne, 2001; Cohen, Manion & Morrison, 2000; Maree, 2016) was performed on tutorial material (Bowen, 2009), mainly deductively (Thomas, 2006), of the content, processes, and activities of the science methodology study guides and tutorial letters, which capture the content and assignments of the undergraduate BEd and PGCE program. Thomas (2006, p. 238) explains that in a deductive analysis one tests "whether data are consistent with prior assumptions, theories, or hypotheses identified or constructed by an investigator". Also, as a hermeneutical procedure (Rockwell, 2003), the analysis aimed to establish to what extent certain phenomena in the tutorial material were in accordance with and conformed to the general rules of canonical PCK. Smith and Banilower (in Berry, Friedrichsen & Loughran, 2015, p. 90) regard canonical PCK as "PCK that is widely agreed upon and formed through research and/or collective expert wisdom of practice." This 'practical wisdom' gained from teachers' classroom experiences is well described by Korthagen (2001). The purpose of this study was to screen the content of the tutorial material against policy intentions and practices. It therefore also captured elements of program evaluation, as I wished to establish to what extent the participants could have benefitted from interventions, and whether we had the skills to teach such a program (Metz, 2007).

Sampling of Participants and Selection of Tutorial Material

The tutorial material of three subject methodologies (Biology, Natural Science, and Physical Science) within this DE department were selected for document analysis. Electronic copies of the module Study Guides and accompanying tutorial letters were selected for analysis. The three modules are compulsory electives to the phase specializations (for example the Senior Phase and Further Education and Training Phase) of both the Postgraduate Certificate in Education (PGCE) and four-year undergraduate BEd-program.

Finally, one senior institutional manager, one senior research professor specializing in distance education, one senior methodologist, and one distance education consultant specialist, were interviewed for 45 minutes regarding their experiences with instructional design applications and practices in distance education.

Meeting Ethical Requirements

Permission to conduct the research was approved by the university executive, the Ethics Committee of the university, the participants' line managers, namely, the chair of the academic department, and the unit directors, Instructional Designer, and Subject Methodology lecturers.

The Nature of Science (NOS), the Nature of Scientific Inquiry (NOSI) and the Science Process Skills

Lederman (1992) explains students' and teachers' conceptions of the Nature of Science (NOS) in the early nineties, and comes to the conclusion that these conceptions differed between the different disciplines and that no "singularly preferred or informed nature of science" existed, and that "the nature of science is as tentative, if not more so, than science knowledge itself" (Lederman, 1992, p. 352). Lederman then draws on the work of both Schwab (1978) and Shulman (1986; 1987) to clarify why the syntactic nature of science happens to be a product of our conception of the Nature of Science, as he puts it. We have been following this approach since the science processes, and the skills to apply these processes, have become part of our science teaching (American Association for the Advancement of Science, 1993; Carin & Sund, 1985; Fraser & Onwu, in Van Rooyen & De Beer, 2007). As a 'belief system' the Nature of Science directs and gives meaning to our pedagogical approaches, and eventually becomes imbedded in our PCK (Loughran, Berry & Mulhall, 2012). Hodson (2009, p. 63) comments that teachers "will not incorporate NOS-

oriented teaching into their curriculum unless they believe it to be important and feasible." The American Association for the Advancement of Science (1993, p. 5) simplifies the way that science, and scientists, operate by explaining that we "deal with abstractions [when] applying our minds (intelligence) to figure out how the world works." There are, of course, many 'scientific methods,' but we know quite well that by using scientific investigation, we give students the opportunity to learn more about the Nature of Science (Vhurumuku, in Ramnarain, 2010), and this is the ultimate goal of science teacher educator programs. Hodson (2009, p. 72) stresses the importance of NOS teaching as follows, "The number one priority, then, is to ensure that teachers and student teachers recognize the importance of NOS teaching and its centrality to the notion of critical scientific literacy."

According to van Putten (2014, p. 4), who quotes Ernest (1988) and Thompson (2009), teachers' (and therefore also student teachers') beliefs have a direct influence on what a person understands about a subject and the way in which the person teaches the subject. In South Africa, for example, all science curricula for primary as well as secondary schools place a high premium on scientific inquiry, as well as on the teaching of science by means of science process skills. For Grades 10 – 12 Life Sciences, for example, such requirements are outlined in the Curriculum and Policy Statement (CAPS) informing teachers which science process skills to embrace during scientific inquiry (Department of Basic Education, 2011). One has to concur with Hodson (2009, p. 209), and numerous other authors he refers to, that the "practices of scientists differ from the kind of activities commonly provided in schools." Realizing that teachers and learners seldom have the opportunity to work with "real scientists," he points to the value of apprenticeships in schools where teachers have to represent authentic scientific practices through modelling (demonstration and explanation), guided practice (guided discovery), and application (free discovery) (p. 208). What scientists actually do is one of the categories of activities that Minner, Levy and Century (2010) link to inquiry. This 'doing' is explained in the pedagogical approaches that teachers employ to allow learners to engage in investigations. The science process skills to follow embrace the syntactical structure of science or the "way" that science could be "done". Collette and Chiappetta (1986, p. 71) argued in the mid-eighties that one of the reasons for including laboratory work in science courses is to "convey science as a way of investigating and as a way of thinking." These thinking, or cognitive, processes have been referred to as science process skills, and are broadly classified as basic skills and integrated skills. Basic skills require of students to observe, classify, observe space and time relationships, use numbers, measure, infer and predict, while the integrated skills are more advanced and capture cognitive functions such as the ability to define operations, formulate models, control variables, interpret data, hypothesize, and experiment. In the South African school science curricula, as well as across the globe, these processes became the foundation for activity-based learning (Fraser & Onwu, in Van Rooyen & De Beer, 2007; Ramnarain, 2010; and Millar, in Wellington, 1989).

Securing Trustworthiness and Credibility

Elo, Kaariainen, Kanste, Polkki, Utriainen, and Kyngas, (2014, p. 3) explain in detail how the trustworthiness of content analysis could be improved by taking into consideration a number of critical measures during the preparation phase. The suitability of the selected research methodology, adequate sampling and securing the unit of analysis within the authenticity of the study, were important criteria to consider. I selected the most appropriate data collection strategy for the review of the tutorial material (deductive document and content analysis, allowing a comprehensive contextual tutorial analysis) as explained in one of the previous and following paragraphs, and located the unit of analysis as science educators' intention to engage student teachers with PCK and SI in the teacher training programs. Furthermore, I analyzed the tutorial material of all subject methodologies dealing with the teaching of Life Sciences, Biology or Natural Sciences as school subjects, and therefore exhausted all possible resources. Lastly, I was led by Bowen's (2009, p. 29) suggestion that document analyses have to be triangulated against supplemental sources of evidence to enhance the trustworthiness of investigations. This I hoped to achieve by interviewing one senior manager, senior research professor, one senior

methodologist, and one distance education consultant specialist regarding instructional design applications and practices.

PEDAGOGICAL CONTENT KNOWLEDGE AND THE TEACHING OF SCIENCE

Science educators have taken it as a given that the notion of Pedagogical Content Knowledge (PCK) gives us a good understanding of how science educators and science teacher educators go about teaching science. I concur with Loughran, Berry and Mulhall (2012, p. 7) that PCK should be regarded as "the knowledge that teachers develop over time, and through experience, about how to teach particular content in particular ways in order to lead to enhanced student understanding." The authors further expand on the notion, capturing explicit actions such as a "combination of the rich knowledge of pedagogy", "shaping and interacting", "better understood" and "the way teaching has been organized, planned, analyzed and presented" (pp. 7 and 8). Such "knowledge of practice" (p. 12) is informed by the substance (content) and syntax (processes) of science, as well as by decades of pedagogical explorations and didactical (methodological) applications.

Kirkham (in Wellington, 1989, p. 137) adds a third dimension, namely, 'context' to the equation, which will be drawn upon later in this paragraph. The command and execution of these skills in teacher training programs, as well as in school science curricula are mandated by curriculum policy (Department of Basic Education, 2011) and demonstrated in science teaching approaches, strategies and methods. Demonstrations, investigations, experimentations, field work, excursions, support, discussions, simulation, plays and explanations, as well as graphs, slide shows, audio recordings, photos, and illustrations, to list a few, are often personalized by teachers to link learners' prior learning experiences, learning outcomes and authentic real-life problems.

Hume and Berry (2010) explain in great detail that it is the responsibility of teacher educators to create opportunities for their student teachers in the teacher training programs to involve in pedagogical reasoning. The authors moreover find that a teacher training program should embrace "PCK in Action" and not only rely on teaching practice to achieve this aim. Garrison, Anderson and Archer (in Garrison, 2007, p. 62) have conceptualized a so-called 'Community of Inquiry' model as an online learning research tool. One of the components of the model, the so-called "Teaching Presence" construct captures three components, viz. design, facilitation, and direct instruction (p. 67). Design (structure) and leadership (direction), according to Garrison (2007, p. 67), are necessary to ensure interaction and discourse. Garrison (2007, p. 67) continues to explain the difference between dialogue and discourse as follows:

"Facilitation supports dialogue with minimal shaping of the course of the discussion. Discourse, on the other hand, is disciplined inquiry that requires a knowledgeable teacher with the expectation that discourse progresses in a collaborative constructive manner and students gain an awareness of the inquiry process".

Minner, Levy and Century (2010) therefore caution that hands-on activities alone might not be enough to guarantee conceptual change. They regard social engagement (classroom discussion) as an important activity that allows its participants to relate meaningfully to inquiry.

However, a "sense of community is based upon common purposes and inquiry" (Garrison, 2007, p. 63). Garrison (2007, p. 63) defines this as "Social Presence," which includes

aspects such as effective communication, open communication, and group cohesion. Garrison and Arbaugh (2007, p. 168) emphasize that it is important "to understand the role of social presence [when] creating a community of inquiry and in designing, facilitating and directing higher-order learning". In this research, I needed to distinguish between a community of inquiry and scientific inquiry at this stage. On the one hand, a community of inquiry is characterized by a strong social (learners), cognitive (inquiry and exploration), and teaching presence (instructional model) (Garrison, 2007). Perry and Edwards (2005), for example, point to the importance of online educators when creating such a community of inquiry. Scientific inquiry, on the other hand, is built on the Nature of Science (Collette & Chiappetta, 1986, p. 48) and "stresses the investigative method of science." Scientific inquiry can therefore be regarded as a way of investigating scientific phenomena, and to do so a number of aspects have to be applied consistently. However, inquiry also relates to non-science specific subject fields (Lasley, Matczynski & Rowley, 2002), while Collette and Chiappetta (1986) have emphasized it within science education.

These 'common principles' or 'aspects' could be regarded as 'common denominators' whose presence would always qualify NOS and NOSI. Gaigher, Lederman and Lederman (2014:3131-3132) refer to them as "aspects of inquiry" or also "common elements of SI" (Lederman, Lederman, Bartos, Bartels, Meyer & Schwartz, 2014:68-71) or 'general aspects of NOSI' (Schwartz, Lederman & Lederman, 2008, p. 4-6). Minner, Levy and Centuri (2010. P. 479) speak of "elements of the inquiry domain." I assumed that the presence of such common elements in tutorial material would be a good indication of authors' acquaintance with the NOS and NOSI. Table 1 illustrates seven common elements associated with scientific inquiry. Each allows staff and students to engage with NOS in a specific way. Lederman (s.a, p. 1) explains scientific inquiry as "the systematic approaches used by scientists in an effort to answer their questions of interest," and further distinguishes between exploring, directed, guided and open-ended inquiry. Bell, Smetana and Binns (2005) confirm such labelling, but add confirmation and structured inquiry to the list.

THE BIOLOGICAL SCIENCES CURRICULUM STUDY (BSCS) 5E INSTRUCTIONAL MODEL

Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook and Landes (2006) refer to earlier sources, claiming that "the sustained use of an effective, research-based instructional model can help students learn fundamental concepts in science and other domains." The BSCS 5E Instructional Model is one such example that has become exemplary in exposing students to the foundations of scientific inquiry. The model has 5 distinct phases or stages, labelled as Engagement, Exploration, Explanation, Elaboration and Evaluation. Siribunnam and Tayraukham (2009) took the model one step further by referring to Elicitation (recall of prior knowledge) and Extension (application of knowledge in daily life) in a so-called 7-E learning cycle. However, 5E engages very well with the Nature of Scientific Inquiry (NOSI) in defining the roles of students and teachers that should emerge during the teaching-learning engagement (Bybee et al, 2006). Table 2, adapted from Bybee et al. (2006, p. 34), aligns the phase requirements with module expectations and instructional requirements.

Table 1. Common Elements of Scientific Inquiry and their Potential Operationalization in DE Systems

Common Elements of Scientific Inquiry (SI)	Operationalization of SI Principles during Teaching and Learning	Relating SI to the Phases of the BSCS 5E Instructional Model
Research questions should guide investigations.	Students should be able to pose, write and defend interesting and viable research questions.	Engagement; Exploration.
Scientific investigations are led by various (multiple) methods.	Students should understand different research methodologies, and be allowed to use different approaches to investigate the same phenomenon.	Engagement; Exploration; Explanation.
Similar procedures often produce different results.	Students applying the same procedures in class often generate different outcomes.	Exploration; Elaboration.
Scientific procedures can influence research results.	Students can engage with investigations under different conditions and obtain different results.	Exploration; Explanation.
Distinguishing between scientific data and scientific evidence.	Students should generate data and be able to differentiate between noise and evidence.	Exploration; Explanation.
Data should generate valid conclusions.	Students should be able to draw conclusions from secondary data or from own experiments conducted.	Exploration; Explanation; Elaboration.
Explanations are drawn from existing bodies of knowledge and multiple data sets.	Students should be able to draw explanations from secondary or from own data and be able to substantiate findings against existing literature.	Elaboration.
The engagement of researchers in a community of practice.	Students should engage with colleagues in a community of practice and be given opportunities to communicate and share information.	Engagement; Explanation; Evaluation; Elaboration.

Table 2. Operationalization of the stages/phases of the BSCS 5E Instructional Model (Adapted from Bybee et al., 2006:2, 8, 3; Minner, Levy & Century, 2010:479)

Instructional Model (5E) Stages	Key instructional activities drawn from Bybee et al. (2006) and Minner, Levy and Century (2010).
Engagement	"Engage learners in the learning task"; "Focus on an object, problem, situation, or event." "Mitigation of cognitive disequilibrium" should be allowed. "Puzzle learners"; "Motivate them actively" (Bybee et al., 2006, p. 2, p. 8, p. 34; Minner, Levy & Century, 2010, p. 479).
Exploration	"Design exploration activities" by creating "common"; "Concrete experiences"; "Initiate the process of equilibration"; "Concrete and hands on activities"; "Generate new ideas" and "explore questions"; "facilitate the actions, observe, listen, and ask probing questions" (Bybee et al., 2006, p. 2, p. 8, p. 34).
Explanation	A common understanding of the terms, concepts, processes and skills should now emerge. Learners "should be asked to give their explanations." Explanations should be given "briefly, simply and clearly." There should be a variety of educational media such as video, slides, photos, graphs and pictures to order ideas and processes mentally. Lecturers should encourage explanations, ask for substantiation, and clarification (Bybee et al., 2006, p. 2, p. 9, p. 34; Minner, Levy & Century, 2010, p. 479).
Elaboration	Lecturers should challenge students and allow them to "present and defend their approaches." Group discussions and cooperative learning is important. They should "receive feedback from others…who are very close to their own level of understanding". "Generalization of concepts, processes, and skills is the primary goal". Lecturers should call for "alternate explanations" (Bybee et al., 2006, p. 2, p. 8, p. 34; Minner, Levy & Century, 2010, p. 479).
Evaluation	Students assess their own understanding. It is important to find out how students have progressed "toward achieving the educational objectives." Lecturers will be looking for evidence, and will observe students and pose questions. The assessment of knowledge and skills is important, as well as the establishment of canonical theories (Bybee et al., 2006, p. 2, p. 8, p. 34).

RESULTS AND FINDINGS OF THE CONTEXTUAL TUTORIAL ANALYSIS

A close analysis the tutorial material brought to light the effectiveness of paper-based material in introducing learners to the focus and objectives of teaching-learning interventions. See Appendix 1. The study guides of two methodologies captured NOS and NOSI well by introducing student teachers to the definitions and constructs thereof, and by providing sufficient examples to reinforce and clarify phenomena. The text could introduce learners to appropriate paradigms of power and could also focus on the development of a scientific attitude and scientific understanding. Asking questions such as "What is science?" assured a first level of engagement. This engagement, however, focused their attention on what they had to know and understand. It also directed readers to specific learning tasks, specific objects, phenomena, problems, occurrences and situations, yet the explored text remained flat and silent, and did not allow itself to be drawn into an argument. The arguments raised in one of the study guides (SG1) were not provocative enough and in-text questions only expected from learners to reflect on their own experiences, add their own examples, provide alternative options, name examples or list

required skills. The second study guide (SG2) emphasized the importance of creating cognitive disequilibrium, which the text did not do, and referred to presuppositions, paths of reasoning, speculative theories (evolution), and non-speculative theories. It further cautioned students to guard against not developing critical independent reasoning, and to teach speculative theory as canon. The first unit concluded by dealing with science as a method. The third study guide (SG3) referred briefly to NOS as a learning outcome, and provided students with the Theory Of Inquiry-Based Learning as a data collection strategy, as well as problem-solving. It showed the premises of exploration by engaging student teachers in an activity to design a problem solving exercise for their learners. Some explanation was provided through the introduction of exemplary case studies and activities to engage learners in inquiry-based learning. Students were further motivated to engage their learners in the design of exploration activities.

The first Tutorial Letter (TL1) that accompanied SG1 expected student teachers to list important science process skills, and then requested them to explain how each should be facilitated in a practical investigation. What followed at a later stage was a question related to the use of different teaching strategies in teaching the subject. What was encouraging was the students' engagement with a so-called e-portfolio, which was submitted as compulsory evidence that they understood the competences of successful science teachers, and showed their ability to design practical lessons. Evidence in the form of lesson plans, photos of artefacts, accompanying documents, and videos were requested. Opportunities were created for students to understand the details of exploration, explanation and elaboration as part of scientific inquiry. TL2 focused on hands-on activities as an ideal way to teach science, as well as the transformation of 'child science' to 'true scientific understanding'. Little reference was made to inquiry as such, or the accompanying skills required to develop IBTL strategies. However, the students were requested to participate in the online discussion forums at least once month. TL3 was more specific regarding PCK and NOS as an epistemology, and science as a way of knowing. The students pointed to the fact that science has to be taught in such a way that learners develop problem-solving and inquiry-based skills.

DISCUSSION

As praxis (see Marshall, Horton & Smart, 2009) NOS and NOSI are quite prescriptive in terms of their rules of engagement and principles of practice. As science educators we engage science students "in the ways of science" and bring them to a better understanding of how scientists go about practicing science on a daily basis. To achieve this, students have to be acquainted with different scientific methods and also with strategies and processes to lodge inquiries, gather data and synthesize findings. The BSCS 5E Instructional Model (Bybee et al., 2006) meet such requirements but the monitoring of the operation is hampered by the capacity paper-based modes of delivery have to offer. Paper-based modes of delivery are powerful enough to support the theoretical needs of learners. They are ideal to introduce learners to the philosophies and paradigms underpinning science and science education, and share theory, policies and practices, but fail to monitor the engagement of learners in communities of inquiry in a short space of time. Science teacher educators use tutorials effectively to provide student teachers with a comprehensive theoretical foundation for scientific experimentation, science process skills and teaching strategies that are appropriate for the sciences. The assignments given in the TL requested students to indicate how they would go about performing certain actions and activities that are related to teaching science. Many of these depended heavily on the recall of knowledge ('what should' actions) or to indicate 'how' certain actions needed to be performed.

Garrison (2007, p. 69) observed that the role of social presence has to be understood in order to create a community of inquiry, and in designing, facilitating, and directing higher-order learning. He reiterated constructs such as "interaction", "group cohesion" and the "modelling of respectful critical discourse." The university defines its mode of instruction as a 'blended model', which does not fit the traditional 'blended' mode of operation with a compulsory 30% on-campus requirement, but rather that of a primary paper-based

correspondence model supplemented by a technology enabled, assisted or supported component. It also follows a 'two-track' approach – everything that is done online also needs to be duplicated in print, and vice versa (Interview with distance education specialist). This approach is however paradoxical: It ensures access for all learners, yet simultaneously devoid learners with limited web-based access to networking, communication and participation in discussion forums.

What was found lacking from some of the tutorial material were sets of actions that teachers should perform in the classroom, which would allow learners to engage with scientific material that encourages IBTL, and exploratory and discovery opportunities. Students could have, for example, been given a number of worked examples (see Tuovinen & Sweller, 1999) explaining to them how a simple experiment could be performed by manipulating the procedure in changing the character of the independent variables. Appropriate case studies would also have been ideal to demonstrate the effective functioning of communities of inquiry. They could have pointed to the activities that student teachers should be allowed to perform when engaging their learners in scientific inquiry. The exemplary nature of the designs should allow them to apply the basic procedures to other situations.

One of the purposes of science education methodology modules is "to introduce the constructs of PCK to student teachers" and to help them to "recognize elements of PCK in action" (Hume & Berry, 2010). This methodology sees PCK as a special form of professional understanding, and poses two strategies, the first of which is so-called Content Representations (CoRes) and the other Pedagogical and Professional-experience Repertoires (PaP-eRs). The former refers to the exposure of students to experienced teachers' entire collection of PCK (knowledge base) required to support learning in a given context, while the latter comprises "narrative accounts" to illustrate PCK in action (Hume & Berry, 2010). They encompass "a detailed description and reflection of teachers' reasoning and reflection" about a specific lesson (Bertram, 2014, p. 293). There is enough evidence to believe that CoRes and PaP-eRs are equally important to help student teachers to teach science better and to teach with understanding (Bertram, 2014; Hume & Berry, 2010). CoRes could be reflected in case studies, and PaP-eRs in students' e-portfolios. The tutorials mostly failed to introduce student teachers to a "collection of PCK" experiences, and also lacked the design qualities to engage them in "communities of inquiry". However, supplementary e-filing systems allowed students to upload evidence of their engagement with scientific enquiry – and the science process skills – during teaching practice.

For more than thirty years now, scholars have been reporting on the importance and value of participative, collaborative and interactive practices to human development. The undeniable value of such practices in classical learning have been confirmed over time in the importance of students' reflections (Leijen, Valtna, Leijen & Pedaste, 2012), the engagement of critical friends in a quality teaching practice (Franzak, 2002), guided didactic conversations (Holmberg, 1983), the value of participatory reflection and action approaches to social research (Chambers, 1994a), the creation of communities of inquiry (Garrison, 2007), engagement in communities of practice (Wenger, 1998), the ideal dialogue of Habermas (McCarthy, 1978), and cooperative learning (Slavin, 1990).

Where paper-based tutorials often lack impact or exploratory power, supplementary support through Massive Open Online Courses (MOOCs) are effective in exposing learners to the practice of IBTL, for example. MOOCS are defined by Czerniewicz, Deacon, Fife, Small and Walji (2015, p. 1) as "massive open online courses (that) are a flexible and open form of self-directed, online learning designed for mass participation." Furthermore, Borba, Askar, Engelbrecht, Gadanidis, Llinares and Aguilar (2016, p. 593) also see them as courses "that offer opportunities as well as challenges for distributing knowledge from institutions." Characteristics such as collaborative learning, learning with others, the promotion of active engagement, the building of peer learning communities, the provision of practical methods, and the support of interaction between colleagues (Borba, Askar, Engelbrecht, Gadanidis, Llinares & Aguilar, 2016) make them very sought-after as a

teaching and learning platform where a multitude of strategies, approaches, and actions have to meet the substantive and syntactical structures of the subject. Classroom Strategies for Inquiry-Based Learning (edX) created by the University of Texas at Austin retrieved from https://www.mooc-list.com/course/classroom-strategies-inquiry-based-learning-edx is a fine example of one such program.

Paper-based DE tutorials still play a fundamental function in educating less privileged learners in especially developing countries, yet fall far short in exposing them thoroughly to the NOS. Such teaching and learning material still have important roles to play in facilitating scientific inquiry in science teacher education programs, but their impact will depend on the success of instruction designers to integrate actions and activities into the tutorials that will create, support and maintain functional communities of inquiry. MOOCS are but one such example, and similar success can be achieved with virtual learning environments (Borba 2016) such as Blackboard Learn™, and blended learning platforms. However, to supplement paper-based tutorials as such, carefully monitored policy-decisions have to be in place as quality vanguard create science communities of practice.

CONCLUSION

The correspondence practice of using written text is still very much in favor of controlling the teaching-learning event as a one-directional activity with limited or occasional interaction. Haughey, Evans and Murphy (2008) locate this practice historically in the behavioral paradigm, which sees educators as the controllers of the learning process in providing adult learners with "highly delineated materials" as a way to guarantee success. This has been the pattern of a first and second generation mode of delivery for many years (See Heydenrych & Prinsloo, 2010).

From a classical qualitative research perspective, transferability addresses the question whether the findings of a study could be transferred to similar scenarios and settings (Elo, Kaariainen, Kanste, Polkki, Utriainen, and Kyngas, (2014, p. 6) or whether the findings are confined to the three modules sampled for this study? International trends that steer and guide scientific approaches and practices, institutional and departmental program polices that oversee the implementation of such practices, as well as academic insight and will to accommodate state-of-the-art technologies in tutorial packages, are universal factors informing program design and development. Where modules and programs are not aligned with faculty and departmental research foci – such as PCK and SI – it is often the experiential learning of individuals that will drive change and innovation. The adoption of a common teaching philosophy is often the only assurance that learners will be exposed to contemporary trends and prominent paradigms that paint the scientific educational landscape.

LIMITATIONS OF THE STUDY

Although Bowen (2009, p. 29) justifies the value of document analysis as a trustworthy stand-alone qualitative methodology, she also points to its role in data triangulation, with the suggestion that studies would become more credible if document analysis could be complemented with other data collection strategies (p. 30). Bowen (2009, p. 30) explains that "when there is convergence of information from different sources, readers … have greater confidence in the trustworthiness (credibility) of the findings". It would have been appropriate to contextualize lecturers' application and implementation of scientific inquiry (SI) and pedagogical content knowledge (PCK), for example against student teachers' responses, to the module objectives and envisaged outcomes as listed in the selected tutorial material. Furthermore, tutorial material describes 'intended' or 'anticipated' behavior, and gives little account of the achieved outcomes. An analysis of student

assignments would have given the researcher further understanding of science educators' engagement with PCK and SI.

FUTURE RESEARCH

It is much of a given that second and third generation paper-based distance education models will remain a prominent feature in the education landscapes of developing countries for a good number of years to come. However, the rapid growth and development of on-line and open distance education practices, call for ongoing research into the alignment and integration of web-based modes of delivery and traditional paper-based models. Furthermore, the practical realities of SI, the teaching of the sciences in general, student teachers engagement with PCK, and accompanying learner engagement and interaction, often prescribe the praxes of the pedagogies of choice. To teach from research, calls for powerful and flexible platforms from where teaching and research could be driven. For example, it is common practice to engage 400 participants in groups of ten in Participatory Reflection and Action (PRA) interventions in open classrooms, but extremely challenging to duplicate similar interventions on-line and at a distance. The interaction between participants (send, receive and reply activities) often have to be done synchronously, calling for group members to participate and be able to share information simultaneously, at a specific time. Paper-based modes of delivery are mainly asynchronous and one-directional. We need to understand the possibilities of institutional on-line platforms better and find out how they could be used to enhance activity-based, problem-based and inquiry-based science teacher education.

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APPENDIX

Summary of the textual analysis of the Study Guides and first Tutorial Letters of three Teacher Education Methodology Modules

Tutorial Material	Reference to NOS	Reference to NOSI	Reference to SPS	Engagement of students with scientific inquiry
Study Guide 1 (Students 389. 163 cancelled)	Linking Positivist paradigm, scientific inquiry, experimentation and skills. Forms of experimentation listed with reference to SPS. Occasional reference to NOS.	Characteristics of science. Specific reference to scientific methods. Reference to NOSI specifically in text and Curriculum Statements.	Emphasizes the development of the SPS. Purpose and importance of SPS explained. Reference to basic as well as the advanced SPSs. Thorough outline to scientific inquiry.	Videos links to scientific methods, controlling of variables, etc. Lesson design to guide learners through investigations. Learning linked to SPSs. Students assessed on knowledge, understanding and application of the SPS. Focuses on Engagement, Exploration and limited Explanation.
Accompanying Tutorial Letter 1	No reference to NOS.	Reference to inductive teaching strategies but not to scientific inquiry, or inquiry in the text.	References to and listing of SPS, the design of practical lessons to guide learners through practicals.	
Study Guide 2 (Students 4888. 188 cancelled)	Very holistic approach followed in becoming good science teachers. One unit focused on science as a method or process. A strong focus on scientific attitude and the development of a scientific understanding. Focus on "What is science?"	Little emphasis on scientific inquiry. Importance of SPS, reasoning and logical argumentation highlighted. Reference to "meaningful activities". Some reference to cognitive development.	No specific reference to scientific inquiry but to "hands-on" activities and experimentation.	Organizing and planning teaching in the Natural Science classroom. Application of various teaching strategies. Construction of materials and apparatus. Lesson planning. Plant and animal maintenance. Assessment. Safety Precautions. Development of scientifically literate learners. Know most ideal ways (methods) to teach science. Focuses mainly on Engagement, Exploration and Explanation. Reference to IBTL.
Accompanying Tutorial Letter 2	Value of experimentation and investigations. Understand the experimental nature of Natural Science.	Questions dealing with inquiry and investigations. Assignment covered experimentation and constructs related to inquiry.	Assignment covered science processes and inquiry. Reference to inquiry-based skills and problem-solving skills.	
Study Guide 3 (Students 221, 54 cancelled)	To approach physical and chemical phenomena with an inquiring mind. Focus on the teaching of (the) Scientific Method, observation, trial and error, verification and forming of deductions. Reference to NOS.	Scientific thinking and processes dealing with IBTL. Very informative about scientific inquiry, scientific methods and science process skills. Reference to NOSI, Curriculum Policy and Practical Scientific Inquiry.	Use science models, theories and laws to make predictions. Practical Scientific Inquiry, SPS planning, observation, collecting information, understanding, generalization, the formulation of hypotheses, communication of information and the ability to draw conclusions. Reference to process skills as related to Curriculum Policy.	Teaching strategies and teaching methods in Physical Science. Inquiry-based, active learning and problem-based learning. Reference to practical lessons, demonstration lessons, theoretical lessons and problem solving. Exposure of student teachers to different teaching strategies. Qualities of good science teachers. Lesson design.
Accompanying Tutorial Letter 3	Reference to NOS.	Understanding Inquiry-Based Teaching. Reference to Inquiry and to IBTL.	Reference to inquiry skills and problem-solving skills.	