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Difficulties in developing a curriculum for pre-service science teachers

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Course outlines for science teachers, designed and developed at 6 universities, were critically analysed and compared with the guidelines for science education set out in the national policy framework known as the Minimum Requirements for Teacher Education Qualifications (MRTEQ) to identify the characteristics of a competent science teacher. Researchers used qualitative means to elicit data from the curriculum documents and in-depth interviews with science teacher educators at the institutions that participated in the study. The analysis of data focused on identifying views and perspectives that informed selection and organisation of curriculum content and pedagogical approaches. The findings that emerged from the data analysis point to both convergence and divergence among science teacher educators in terms of (i) interpretations of the policy on the minimum requirements for teacher qualifications, (ii) conceptualising hybridisation of academic content knowledge from different disciplines in the fields of science, and (iii) conceptualisation of pedagogical content knowledge for integrated approaches to teaching and learning of knowledge. A lack of uniformity in the conceptualised academic content and the conceptual framework to develop pedagogical content knowledge for the interdisciplinary school subject, Natural Sciences, pointed to the challenges facing departments of sciences education to produce competent teachers.

Keywords: conceptualisation; curriculum development; knowledge integration; science disciplinary content knowledge

Introduction

In terms of conceptualisation of the paradigm shift for teacher education and training, educational and curriculum transformation in South Africa after liberation caught many university faculties off guard. Researchers in South Africa highlight the fact that educational transformation, and the changes and continuities that curriculum streamlining entailed, were threatened by ill-preparedness of the cohort of teachers employed in the school system (Chisholm, 2005; Darling-Hammond & Bransford, 2005; Jansen, 2002a; Taylor, 2007). Critics of curriculum changes for the General Education and Training (GET) band argue that the chaos in teaching and learning in elementary schools and the Senior Phase arose because teachers could not interpret and comprehend the radical curriculum changes correctly (Hoadley& Jansen, 2009; Jansen, 2002b). Researchers claim that the teacher is the key factor in the process of curriculum change and that, if teachers are not adequately equipped with the necessary conceptual knowledge and pedagogical content knowledge, the proposed curriculum will face challenges and threats at the implementation phase (Carl, 2012; Fullan, 2007, 2008; Ornstein & Hunkins, 2014).

In this paper we provide a historical perspective of teacher education and training in the context of South Africa by indicating the diversity in the philosophies and theories that informed the development of the curriculum structured for the programmes of teachers' qualifications (Christie, 2008; Hoadley & Jansen, 2009; Kraak, 2000). Morrow (2007) argues that fundamental pedagogics was the philosophical foundation which the academics of the National Party (1949–94) adopted to entrench the beliefs and principles of white supremacy at teachers' education and training institutions. Pioneers of fundamental pedagogics were condemned for producing teachers who were deprived of academic skills and attributes like critical and creative thinking skills, and research and inquiry skills. Apartheid-trained teachers lacked assertiveness and pro-activeness (Jansen, 2002b; Kallaway, 1989) because, by definition, they were taught to be obedient foot soldiers.

Progressive approaches to pedagogy adopted by neo-liberal and liberal scholars and academics in teacher education enable pre-service teachers to re-think teaching and learning. Ideas of constructivist strategies introduced teachers to progressive knowledge of pedagogy in dominantly liberal universities. This background was critical to the study: the majority of academics who are currently employed at university faculties of education in this country are influenced, consciously or unconsciously, by this historical background.

Views contrary to those of liberal and neo-liberal researchers were expressed by Samhoff (2008) and Weber (2008) who argue that liberation movements in the 1990s advocated that educational transformation should uphold a socialist revolutionary perspective to replace liberal philosophies and ideology (Alexander, 2001; Badat, 2004). Hoadley and Jansen (2009) interpret the introduction of the outcomes-based education system and its principles in South Africa to be the radical reaction of the ministry of education under the leadership of the African National Congress (ANC) to the socialist revolutionary perspective (Habib, 2001; Habib & Parekh, 2000).

This study was conducted by means of multiple case studies at the departments of science education at six universities. This study was intended to determine the impact of diverse philosophical beliefs upon the conceptualised science teacher who is competent to comprehend conceptual academic knowledge and pedagogical content knowledge required in the teaching and learning of Natural Sciences subject content in classrooms.

Literature Review

This study was framed from ideas and views about knowledge integration in the teaching and learning of science and in curriculum development in general. The concepts of curriculum change, curriculum development, and knowledge integration were explored widely for the purpose of understanding the theoretical basis of practical curriculum development. Literature indicates that the term "knowledge integration" is used interchangeably with "integrated curriculum" in educational and curriculum research (Barnett, 1997; Barnett & Hallam, 1999; Gibbon, Habib, Jansen & Parekh, 2001; Gibbons, 2003, 2007; Gibbons, Limoges, Nowotny, Schwartzman, Scott & Trow, 1994; Luckett, 2009).

The concept of knowledge integration lay at the heart of transformation of education and curriculum advocated by the South African Qualifications Authority (SAQA) and the National Qualifications Framework (NQF) for attaining national educational goals termed "critical cross-field outcomes" (CCFO) (Department of Education and Training, 1997). The Norms and Standards for Educators (Department of Education, 1998) provided guidelines for developing a curriculum for teacher qualification which aimed to equip teachers with academic subject content knowledge and subject pedagogical knowledge in science education.

Literature points out that the transformation of the curriculum for teacher education and training in the faculties of education was chaotic: teachers who graduated from the teacher qualification programmes were largely incompetent in all professional aspects, academic subject content knowledge, and pedagogy (Department of Higher Education and Training [DHET], Republic of South Africa, 2011a, 2015; Morrow, 2007; Muller, 2006; Taylor, 2007). The national Department of Education ([DoE], 1997) introduced the seven roles of educators as attributes for graduate teachers in the democratic educational dispensation. These roles were integral parts of outcomes-based teacher education and training. Hoadley and Jansen (2009) and Samhoff (2008) argue that the radical policies introduced by the Department of Education from 1996 to 1998 to transform higher education in South Africa, ushered universities, and particularly teachers' education and training, into turmoil. This narrative highlights the challenges faced by academics in many faculties of education. Hoadley and Jansen (2009) explain that academics were not given sufficient time to conceptualise the outcomes-based paradigm in teacher education and training.

Badat (2004) indicates that faculties of education struggled to design qualification programmes and to develop academic content knowledge for the broad-field curriculum which is characterised by melding or hybridisation of two or more related subjects, because they lacked philosophical and conceptual knowledge, theoretical principles, and the knowledge of pedagogical approaches. Alexander (2001) and Badat (2004) elaborate upon the challenges of redesigning curricula for the programmes which could adjust teacher qualifications to suit changes of the school-based curriculum in South Africa. The Minimum Requirements for Teacher Education Qualifications (MRTEQ) highlights that academics lacked skills and expertise in curriculum design and development. The guidelines provided by MRTEQ were interpreted differently by academics. The issue of knowledge integration for school broad-field curriculum design for schools and the curriculum design for integrated learning was a point of debate.

The protagonist perspective was developed from literature based upon international and local research. Proponents of this perspective are influenced by the theory of Mode 2 knowledge production, which was pioneered in educational research by Gibbons et al. (1994). The influence of Mode 2 knowledge production in South Africa was proposed by researchers of the curriculum model for the democratic society led by the National Education Crisis Committee ([NECC], 1992). The trend set by the NECC researchers was supported by researchers in higher education (Clark & Linn, 2003; Department of Education and Training, 1997; Nowotny, Scott & Gibbons, 2001).

Innovations introduced by the Higher Education Qualifications Framework (HEQF) (DHET, Republic of South Africa, 2011a) and the South African Qualifications Authority (DHET, 2011b) set out certain competences and attributes for a competent science teacher in a democratic education dispensation. The competence-based approach and broad-field curriculum design indicate that teacher education and training should adopt a new paradigm for re-thinking and re-conceptualising strategies of teaching. The outcomes of learning should be demonstrable in application: outcomes should emerge through problem-based learning, inquiry-based learning, reflections, research, and collaborative engagement in the composition of academic subject-content knowledge in the science education curriculum for teacher education and training (Carlile, 2004; Darling-Hammond & Bransford, 2005; Edwards, 2011). According to curriculum guidelines for developing course outlines in teacher education and training, the emphasis should be on the integration of knowledge, learning, and competences (DHET, 2011b, 2015). The perception of integration held by the policy formulators of the DHET pointed to the importance of integrated knowledge acquisition to be the demonstration of theoretical and practical applied competences by students in the education and training programmes.

Kraak (2000) and Luckett (2009) argue that thinking and reflections in educational research should promote knowledge integration for conceptual knowledge and procedural knowledge. Barnett, Parry and Coate (2001) and Young and Gamble (2006) conceptualise knowledge integration as a paradigm that could transform universities from being passive reproducers of knowledge into spaces of authentic knowledge production in South Africa and globally. Gibbons (2003, 2007) and Ogunniyi (2004) emphasise the importance of engaging students and academics in knowledge production so that both academics and students acquire competences and are made aware of global and local socioeconomic and technological advancement. Thompson and Warnick (2007:10) reiterate this narrative: "in the teaching and learning in universities, the paradigm shift from discipline based to knowledge integration will be possible through, trans-disciplinary, problem-based learning (PBL), thematic-approach and inquiry-based learning (IBL)."

Theoretical Framework

The theoretical framework of the study was crafted from ideas of the practical and critical praxis, pioneered by the theorists in curriculum research, development, dissemination, and adaptation (RDDA) (Kelly, 2009; Null, 2011; Ornstein & Hunkins, 2014). The critical praxis emphasises the blending of action and inquiry by reflecting upon what it means to engage in worthwhile learning experiences. Carl (2012:49) explains that a practical paradigm accommodates the role of human agency and that curricular knowledge needs to be recognised as a social construct by which human actors in the learning process reach a consensual understanding of what is to be studied. This theoretical framework highlights an assumption in this study that science teacher educators in universities have reached a consensual conceptualisation of the model of integrating academic disciplinary knowledge and pedagogy that could enable pre-service teacher to teach Natural Sciences effectively to senior phase learners.

The theoretical framework included a synthesis of models of knowledge integrated for the purpose of locating the trends that could have influenced and informed conceptualised academic subject content knowledge and pedagogy for pre-service natural science teachers. Proponents of knowledge integration such as Davis (2004), Edwards (2011),Gibbons (2007), Gibbons et al. (1994), Kuutti (2007), Luckett (2001, 2009), and Repko (2008) point out that knowledge integration implies re-organising, sequencing, and re-structuring knowledge composition in the various disciplines. According to Ornstein and Hunkins (2014:164) reorganisation of content knowledge in the context of broad-fields curriculum design entails melding the fragmented and compartmentalised discipline-based content from related subjects into areas of learning. Proponents of this trend commend this approach to curriculum development for facilitating hybridisation of content and knowledge in both knowledge construction and ped agogy, enabling students to make connections among related themes and conceptual knowledge across disciplines (DHET, 2011b; Kuutti, 2007; Luckett, 2009).

Fogarty (1991:62) proposes various models for implementing knowledge integration: integrating knowledge within the discipline could be effected by means of "connected" models and "nested" models. Such models emphasise interconnections between disciplines by connecting related concepts, skills, and ideas to one topic. In the case of science, aspects of geology, astronomy and biology could be dealt with under a single unifying theme or organising principle (Fogarty, 1991:61). For knowledge integration across disciplines, the following models are recommended: sequencing, and shared, webbed, and integrated models. These models may differ in practice, but they all focus on the crossing of epistemic and theoretical boundaries in the broadly identical process of knowledge composition and pedagogy in curriculum development. In the sequencing model knowledge is organised into a coinciding sequence. The shared model entails clustering ideas, concepts, and skills from overlapping topics or themes. The focus in this model is on key concepts, attitudes, skills, and ideas, which could be duplicated unnecessarily if taught in separated, distinct disciplines. The webbed model requires organisation of knowledge into broad themes or units, which are to be generic or provide fertile ground for development of conceptual knowledge that emerges from common ground, much like sprouts or shoots. The threaded model emphasises identification of big ideas to be linked up for the acquisition of conceptual knowledge, cognitive, social, and affective skills across disciplinary divides.

Research Design and Methodology

An interpretive, constructivist paradigm was chosen to frame this research project (Creswell, 2009:8; Denzin & Lincoln, 2008:3). A constructivist paradigm emphasises the socially constructed, transactional nature of knowledge generation occurring between a researcher and participants.

Research Design for Qualitative Data Collection

Case studies were the preferred design for this research project. The restructuring of the higher education institution merged the historical universities with colleges of education and technikons.

The following categories were considered as case studies in the design of the research.

Case study A

This case study focused on higher education institutions which emerged after the merging of the historical technikons and colleges of education, and are now called universities of technology. For ethical considerations, confidentiality, and anonymity, the pseudonyms H and V are used to refer to these institutions.

Case study B

This case study focused on two historically white universities. They are referred to as K and L in the discussion and data analysis.

Case study C

This case study focused on universities that merged with former colleges of education which were historically homeland universities (reservation colleges in United States [US] and Australian terminology). These institutions are referred to as P and N in the discussions.

Qualitative method of data collection

The case study research design enabled the researchers to use qualitative methods for data collection and to triangulate instruments for the purpose of validating data as proposed in Creswell (2009:14). The first set of data was collected by means of analysis of course outlines and study guides, and audio-recorded in-depth interviews, which were transcribed into written transcripts.

Sampling

The sampling procedure was purposive, implying that desirable participants were selected. The target population was life science education teacher educators in faculties of education. The sample comprised 12 life science teacher educators. In each case study two participants were approached to participate in the study and permission was granted by the gatekeepers at institutions. Participants were assured of confidentiality and anonymity.

The context under which this research was undertaken during the course of curriculum development for life science education in the selected universities was significant, and constrained the process of organisation of data collection, because many teacher educators were sceptical about their curriculum blueprint sent to the DHET for approval.

Data Analysis

The data gathered from documents was analysed and presented in tables according to the key areas used to focus the analysis, which were reorganisation of content knowledge, strategies of curriculum delivery, pedagogical approaches, and purpose of the course. Pseudonyms, for instance Y, Z, Q, S, V, and G, were assigned in the discussion to cite participants' views highlighted during analysis of qualitative data.

Case study A (H&V)

Content organisation: Life sciences, physics and chemistry are called compulsory electives for students who specialised in sciences.

Course: Natural Sciences 1

Purpose of the course: The purpose of this elective subject is to prepare students for further study in life science, physics and chemistry in the Further Education and Training (FET) phase in the third and fourth years of study.

Table 1 Organisation and sequencing of science education content knowledge for first and second semesters of academic year level one

First semester	Second semester
This elective subject is divided into three disciplines of science namely life science, physics and chemistry; To link all the different metabolic processes in both plants and animals with the disciplines of chemistry and physics; To become a subject specialist in Natural Science with a keen awareness of the value of Natural Science in a dynamic and diverse teaching and learning environment.	
Life Sciences/Biology 1 • Scope of knowledge: Cell structure, cell communication and cell division, introduction to genetics and molecular biology, diversity on earth, animal diversity. **Curriculum Studies 1** (*subject pedagogical content knowledge)* Contextualising natural science teaching and learning within Curriculum and Assessment Policy Statement (CAPS), teaching and learning theories, the nature of science and biology; Deliberating what science is about and the role of science teaching in the Senior Phase; Materials, media, and safety in the teaching of natural science in the Senior Phase; Matching learners in the Senior Phase to possible teaching styles in the natural science classroom; Designing basic lesson plans for teaching Natural Science in the Senior Phase.	**Physical Sciences 1** • Scope: Molecules, matter and materials, chemical bonding, chemical reactions, energy. **Curriculum Studies** Deliberating what science is about and the role of science teaching in the Senior Phase; Materials, media and safety in the teaching of natural science in the Senior Phase; Matching learners in the Senior Phase to possible teaching styles in the natural science classroom; Designing basic lesson plans for teaching Natural Science in the Senior Phase.

Natural Science 2

Purpose of the course: understanding of fundamental concepts, theories, and laws that govern the discipline of science.

Science education subject content knowledge is organised into three modules in the second-year course. The first semester modules focus on the specialised subject content knowledge of life science (biology) and chemistry whereas second semester courses are physical sciences and curriculum studies (see Table 2).

Table 2 Organisation and sequencing of knowledge domains in science education content knowledge for first and second semesters of academic year level two

First semester	Second semester
Life Sciences/Biology 2 Examples of topics: cells, anatomy, (animal and plant), plant form and functions, transport, plant nutrition and soil **Chemistry 2** • Scope: Under matter and materials students will be introduced to the nature of molecules i.e. what it is made up of in order for students to understand the basic chemical building blocks of life. Other sections will also include chemical bonding, chemical reactions and various other fundamentals about chemistry to link the sections done in life science to chemistry in order for students to have an overview of the chemical make-up of the different cells and its chemistry in the body. Basic principles, theories and laws about liquids, intermolecular gases, and electrochemistry. Strategies of curriculum delivery: lecture, independent self-study, practical work, group work Pedagogical approaches: Information communications technology (ICT) integrated approaches **Curriculum studies 2** (subject pedagogical content knowledge) Processing skills applicable to science culminating in an elementary investigation; Materials, media, and safety in the teaching of Natural Science in the Senior Phase; Matching learners in the Senior Phase to possible teaching styles in the natural science classroom; Designing basic lesson plans for teaching Natural Science in the Senior Phase.	**Physical Sciences 2** Examples of the scope: forces, energy and power, electricity, bodies in motion, mechanics **Curriculum Studies 2** (subject pedagogical content knowledge) Deliberating what science is about and the role of science teaching in the Senior Phase; Materials, media, and safety in the teaching of Natural Science in the Senior Phase; Matching learners in the Senior Phase to possible teaching styles in the natural science classroom; Designing basic lesson plans for teaching natural science in the Senior Phase.

Case study B (K&L)

Table 3 Organisation and sequencing of subject matter adopted by institutions to offer science education subject content knowledge (SCK) and subject pedagogical knowledge (SPK) in the faculty of education to enable teachers to teach Natural Sciences in the senior phase and Life Sciences in the FET phase

	Subject content knowledge (SCK)	Subject pedagogical knowledge (SPK)
First year	Chemistry1, Physical Science 1, Mathematics 1/Botany/Zoology 1	Specialised Pedagogical Content Knowledge 1
Second year	Chemistry 2, Physical Science 2, and Botany2 or Zoology 2	Specialised Subject Pedagogical Content 2 Work-integrated learning
Third year	Choice of two majors	

Case study C (N&P)

Table 4 Organisation and sequencing of subject matter content knowledge in the faculty of science and subject pedagogical knowledge in the faculty of education to enable teachers to teach Natural Sciences in the Senior Phase and Life Sciences in the FET phase

		Courses in Faculty of Education
First year	Chemistry 1, Physical Science 1, Mathematics 1/Botany/Zoology 1	Specialised Pedagogical Content Knowledge 1
Second year	Chemistry 2, Physical Science 2, and Botany2 or Zoology 2	Specialised Subject Pedagogical Content 2 Work-integrated learning
Third year	Choice of two majors	

Findings

The process of data analysis was undertaken in terms of the conceptual framework and the framework for the study. The image of the competent teacher for the natural sciences school curriculum could be depicted in the conceptualisation of the organisation of the subject curriculum content knowledge and the pedagogical content knowledge by science teacher educators. The following themes were generated from the theoretical and conceptual framework during analysis of data and identification of findings:

- selection of content and organisational patterns in the broader field of natural sciences;
- Subject pedagogical content knowledge (SPCK) for pre-service natural science teachers;
- Divergence in views depicting historical context and diverse cultures and ideological background as attributes to the conceptualisation of curriculum design for natural sciences.

Theme 1: Selection and Organisational Patterns of Academic Content Knowledge in the Broader Field of Natural Sciences

Case study A represented a university of technology and indicated that the faculty of education was responsible for offering both disciplinary content knowledge across sciences knowledge domains and the sciences pedagogical content knowledge. The data presented in Table 1 point to the modularised disciplinary content knowledge and curriculum studies.

Firstly, in this case study, the naming of the course, Natural Sciences, for year one to year four resembles that of the school-based curriculum. Secondly, the semester courses focus on each separate knowledge domain.

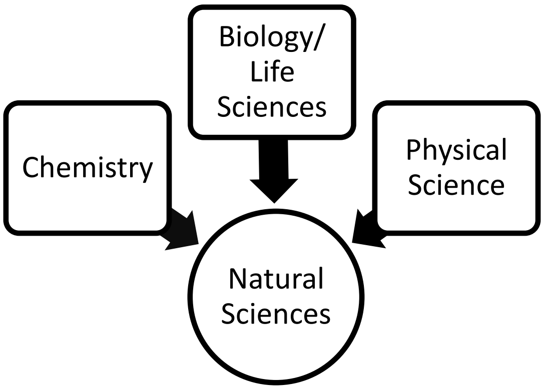

Figure 1 Model of organisation and sequencing of disciplinary content knowledge for pre-service natural science teachers conceptualised in case study A

The modularised sciences subject content knowledge for teacher education illustrated in Figure 1 highlights science teacher educators' perceptions of the balanced knowledge for preparing competent science teachers for the natural science school curriculum.

Thirdly, the subject pedagogical content knowledge was not explicit on the teaching strategies used to implement knowledge integration that students should apply in their teaching of natural sciences topics or themes in classrooms.

Case studies B and C

The organisation of disciplinary content knowledge to equip natural sciences pre-service teachers presented in Tables 3 and 4 point to the different approaches adopted by academics in various science education departments. The modularised subject content knowledge offered to natural sciences students in the science education department in the faculties of education represented in case studies B and C is categorically discipline based; meaning that each discipline maintains its identity. In this category, although the curriculum structure looks the same, the delivery differs. Case study B, which was of a historically traditional university, worked with academics in the faculty of sciences to equip students with adequate levels of disciplinary knowledge in each science knowledge domain; for instance, Chemistry 1, Chemistry 2, Physical Science 1, Physical Science 2 and at least two of the life sciences disciplines e.g. botany, human physiology or zoology. The natural science teachers attended educational and curriculum study modules in the faculty of education and in the science education department.

Theme 2: Subject Pedagogical Content Knowledge (SPCK) for Pre-Service Natural Science Teachers

Qualitative analysis of information elicited by means of in-depth interviews with two participants for triangulation purposes highlighted that the academics in the science education department were not specialists in all disciplines in the field of science.

In response to the question, What approach to academic content knowledge organisation do you consider appropriate for enabling science teachers to teach Natural Sciences in senior phase?, participants at institutions N and P responded as follows.

> Participant V: *It is a challenge to have a teacher who could teach all knowledge domains in the field of sciences. We ourselves do not have the knowledge of all domains or disciplines ... I mean when I teach science I am more biased to the knowledge of the discipline I specialised in. I really think students have to specialise in order to be competent in at least two discipline, for instance, physics and chemistry or biology and physics.*
>
> Participant Q: *In my view, students as they do modules in my institution, each module equip them with sufficient science academic disciplinary content knowledge. And these modules are taught in the mother faculty ... the faculty of science ... why faculty of science? ... We do not have specialists and necessary resources in the faculty of education, for example well equipped laboratories, laboratory technicians, and chemistry and physics specialists with level of academic qualifications in these disciplines required for employment at this university.*

Case study C

The discipline-based academic knowledge is organised into semester modules and each module presents content knowledge that also addresses the principles and conceptual knowledge. The difference between Case studies B and C lies in the curriculum delivery, as it was indicated that in B discipline-based content knowledge is offered by the faculty of science to students who intend to be natural science teachers in the Senior Phase (SP) and distinct science subjects in the Further Education and Training (FET) phase. In case study C both academic disciplinary knowledge and subject pedagogical content knowledge was offered in the science education department. The lecturers offered modules that matched their specialised academic science knowledge. For instance, physical science, chemistry and life sciences were taught by different lectures respectively from year level 1 to year level 4.

The pedagogical approach to teaching and learning was the Dialogical Argumentative Instructional Model (DAIM). This model was founded on the views pioneered by Ogunniyi (2004) to integrate socio-cultural or indigenous knowledge in the mainstream subject matter in science education. The notion of the 5E Kings Models, which is an acronym for the five Es -engage, explore, explain, evaluate, and ensure, was pioneered by Duran and Duran (2004:52) to enhance the development of scientific skills in the learning of subject matter in life sciences. The ideas and views expressed in the course guides in this case study resonated with the values of the DAIM and 5E Kings models to enforce integration of subject matter in the pedagogical teaching and learning of life sciences teachers.

The data collected from triangulation through in-depth interviews to probe information for further clarity on the findings was obtained from document analysis. Two academics volunteered to provide convergent information about these approaches. Figure 2 presents the pedagogical model that could benefit life sciences teachers to develop competences and skills required to teach the broad scope of subject matter in the natural science school curriculum (CAPS) in the Senior Phase.

The respondents responded to the question, What is the value of the King 5E's in preparing your students in science education departments to understand integration of knowledge across the disciplines in the field of science and to prepare teaching natural sciences in Senior Phase, as follows:

> Participant Y: *King 5E's enable our students to be creative and proactive in their learning. This is how it works: firstly, students are given the topics which require students in curriculum studies, to engage in the inquiry for conceptual knowledge and meaning; students are provided with problems so that they could explore for solutions, Explain entails providing own interpretation and comprehension. Expand requires students to develop assumptions from the information, and lastly, ensure entails verification and validation of information.*
>
> Participant Z: *The King 5E is the simplest way to implement the Dialogical Argumentative Instructional Model (DAIM). The proponents of this model are of the view that teaching and learning of any knowledge in the field of science should promote active participation of students in the processes of knowledge construction. The teaching and learning in sciences should promote deductive and inductive methods of knowledge production.*

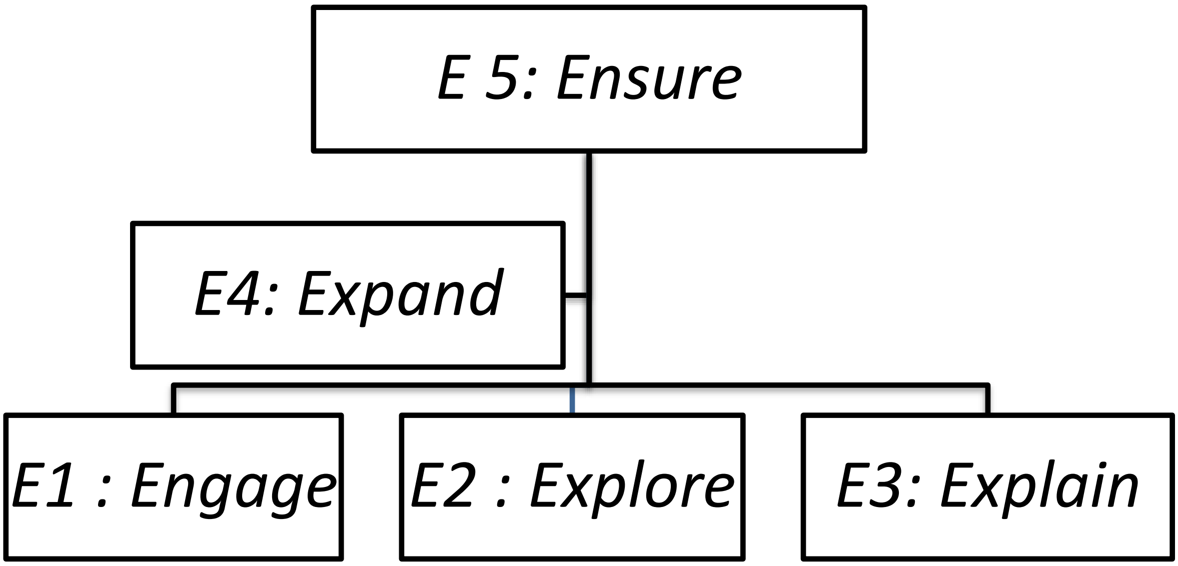

Figure 2 Model of the conceptual pedagogical approach to integrate acquisition of scientific knowledge and skills in life sciences

Theme 3: Divergence in Views Depicting Historical Context and Diverse Cultures and Ideological Background as Attributes to the Conceptualisation of Curriculum Design for Natural Sciences

Qualitative data obtained from in-depth interviews was analysed as follows:

Main Question: What approach to academic content knowledge organisation do you consider appropriate for enabling science teachers to teach Natural Sciences in senior phase?

> Participant S: *First, you should understand that a deliberation on what should be taught was informed by the availability of lecturers and resources. Secondly, we are one institution but with diverse backgrounds in terms of mind-set, ideological beliefs and academic qualifications.*

Follow up question: Do you mean, these factors manifested in the process of brainstorming the curriculum structure or interpretation of the MRTEQ?

> Participant S: *These are the realities we have been trying to cope up with after the merger. Actually, I am saying that certain people were elected to represent each discipline in the curriculum committee. Our representative, for instance, presented what we discussed in our cluster; however not all what we decided was accepted by the curriculum committee. It was in those instances, where bureaucracy and ideological influences manifested.*
>
> *The product presented to you, which is our blueprint, is not hundred percent representative of our opinions as a cluster. The colleague who presented our draft to the committee was overwhelmed by the dominant view which emphasised the maintenance of former curriculum structures.*
>
> Participant G: *I am comfortable with the curriculum design decided upon by the committee because actually my belief is that students should be taught in-depth knowledge from each discipline. It also accommodates our areas of specialisation, for instance, I specialised in physical science and I have been teaching it for many years. I teach my own semester course or module and my colleagues in the cluster teach their own disciplines.*

Follow-up question: In your opinion, will this approach enable students to acquire competences to integrate knowledge in sciences to teach natural sciences in the GET Band?

> Participant G: *I think so - if they have mastered the command of all the knowledge from these disciplines meaning physical sciences, chemistry and life sciences, they could teach each topic in the school curriculum. I prefer it the way we were taught during the apartheid educational dispensation because we managed to acquire specialised knowledge, and this actually made us specialists. No academic in science, if any, they are few in number who specialised in all three disciplines.*

Discussion

The synthesis of the main findings from the document analysis and in-depth interviews is summarized below, as each of the issues that came to the fore seemed to be a key challenge in the development of the curriculum for pre-service teachers of natural sciences at the universities that participated in the study.

The first issue was that of the limited time frames allowed for change and implementation of the natural science curriculum in schools and in the faculties of education at universities. The findings highlight that the process of curriculum change for teacher education had been a trial-and-error method ever since the inception of educational transformation in the democratic dispensation. The issue of accreditation of teacher qualification programmes had been a cause for concern for academics, because it widened the gap between the phasing out and phasing in of programmes. The study highlights the incompatibility between the radical changes and the historical contexts of the institutions. The merged institutions (Case Study A) were caught in the dilemma of restructuring their physical and human resources, which had its own dynamics. While grappling with diverse ideological and cultural issues, and antagonism towards the transformation policies for higher education, the DHET expected of some institutions to develop curricula for teacher qualification at the same time. This finding confirms the work of Habib (2001) which pointed to structural landscape of Higher Education Institutions (HEIs) after amalgamation as the factor in the ongoing instability in universities South Africa. Inadequate level of competence required in higher education and training among the academic staff was highlighted by participants from merged universities as the challenges facing the development of Natural sciences curriculum for pre-service teachers. According to practical praxis and critical praxis the issue of context and time frame are key factors in the development of a sound curriculum. The issue of time is critical because collaboration and debates in the process of decision-making require interaction about the philosophical foundations and the appropriate paradigm for the new curriculum.

Secondly, the uncertainties and diverse interpretations of the aims and goals of the curriculum policy guidelines by teacher educators contributed to the turmoil in the designing and development of the appropriate curriculum for pre-service natural sciences teachers. This study provides evidence that universities often uphold an outdated conception of the curriculum model for science teacher education and training, which was contradictory to that of the Department of Higher Education. Such divergence of opinion between institutions of government and academia is lamentable: both should be partners in transformation to the advantage of young learners. It was evident that some academics were still in pursuit of the pedagogics curriculum structure and modes of delivery, whereas the DHET advocated a modern, integrated approach to knowledge production, acquisition, and curriculum delivery aligned with emerging global trends.

The findings highlight uncertainty in the conceptualisation of the natural sciences school curriculum and the organisation of content knowledge by academics who believe in modularisation of discipline-based content. We interpreted this trends as the maintenance of compartmentalised discipline knowledge; the recycling of the old product under a different name.

The third issue was the lack of uniformity and synchronicity that should have prevailed between the natural sciences researchers and developers at the Department of Basic Education, and teacher educators in departments of science education at universities. The theorising of the curriculum development for natural science teacher education and training by academics and curriculum developers in the participating universities was in contrast with the proposal of Carl (2012:49), namely consensual understanding of what is to be studied. According to the proponents of the critical and practical praxis paradigm, curriculum developers are expected to collaborate in debates and analysis of socio- political and economic contexts in which the process of curriculum transformation takes place (Carl, 2012; Fullan, 2007, 2008; Pinar, 2012). In the South African context, the legacy of segregation principles entrenched through fundamental pedagogics in many faculties of education is the key issue that requires critical analysis and debate by academics at universities before the new paradigm or model for curriculum design and development can be decided upon. The total dominance of the white ideological perspective and conception of culture from 1949–94 caused many teachers to lose their rights to voice and agency in curriculum development. A culture of free inquiry had to be nurtured from grassroots in tandem with curriculum transformation. The issue of bureaucratic impediments regarding the approval of the selected and sequential organisation of curriculum content arose in many faculties of education (Hoadley & Jansen, 2009; Jansen, 2001). The issue of curriculum had never been an arena of consultation and consensual discussions and debate under the colonial or Nationalist regimes. Academics were ill-equipped to engage in the issue of curriculum design and development. Many wished to retain the status quo due to the lack of expertise in curriculum developments and because they preferred what they knew. The findings indicate that universities had experienced hardships in obtaining accreditation for their Bachelor of Education qualification because their curriculum designs were not competently developed. We interpreted this delay as another aspect that contributed to the difficulties of developing the curriculum for pre-service teachers of natural sciences.

The fourth issue was the lack of a model for knowledge integration. The findings highlight that universities had not taken heed of the recommendations proposed by the proponents of knowledge integration in terms of knowledge organisation and pedagogical approaches (Barnett, 1997; DHET, 2011b, 2015; DoE, 1997, Kraak, 2000; Luckett, 2009). According to Fogarty (1991), Gibbons (2003, 2007), Kuutti (2007), and Luckett (2009), knowledge integration is possible through the following approaches: thematic, problem-based, and inquiry-based teaching and learning. However, Case Study C indicated that the King 5E and Dialogical Argumentation Instruction models were initiated to expand students' horizons of knowledge in the field of sciences. This was the confirmation of knowledge integration which Fogarty (1991) referred to as the connective or nested model, which promotes interconnection between knowledge domains in the broader field of knowledge. According to Kutti (2007) and Luckett (2009), the promotion of integration is possible through problem-based learning, inquiry-based learning, and interdisciplinary learning. In order to inculcate the competences in multidisciplinary knowledge integration, Gibbons (2003) recommends that educators should organise a broad theme, which enables students to solve problems while drawing upon conceptual and procedural knowledge as well as skills from related disciplines.

We conclude that without adopting a modern system of knowledge integration, the country cannot produce teachers who will improve teaching and learning of science in schools and bring it on par with that of other countries. As a result, learners may never know that science is a crucial, innovative and exciting way of thinking about real-life systems. Thompson and Warnick (2007:10) emphasise that teacher educators should design a pre-service curriculum incorporating basic science classes that help future science teachers develop necessary science skills. In the area of pedagogy, science teachers require guidance from teacher educators during their training to acquire teaching strategies to implement knowledge integration in the classroom and science laboratory. It is recommended that students at undergraduate level engage in activities that spark and stimulate new connections and vital patterns of thought, but how can they do so under the present circumstances, caught in a cycle of obstruction and recalcitrance?

Conclusion, Implications and Recommendations

The findings of the study raise questions about the perceptions of some academics and teacher educators about the involvement of the Department of Higher Education in the articulation of teacher qualifications and curriculum development. This question emanates from the contradictions displayed by data from document analysis and in-depth interviews. Based on the contradictions shown, we conclude that these two institutions, universities and government, take different directions. The questions that arise are what the rationale is behind academics' and pre-service teacher educators' reluctance to comply with the modernising initiatives of the curriculum guidelines of the DHET? Do the proposed changes and re-conceptualisation of the curriculum for science teacher education and training threaten enshrined views and aspirations of old-guard academics and teacher educators? Why do academics and teacher educators disregard the notion of integration in the science education curriculum for teacher education out of hand?

The findings of this study cannot be generalised on the following grounds: the study was undertaken during the process of curriculum design and development at universities. The sample did not involve all 21 universities in South Africa, but only six. The issue of documents was a constraint because some institutions considered these as the proprietary intellectual property of academics. The documents analysed in this study were from only four of the six participating universities. However, the data from in-depth interviews substantiate that the content of the documents represents to some degree the knowledge of the scope of typical science modules and courses.

It is recommended that future research should cover other aspects of core questions raised by the findings of this study. Implementation of the curriculum, for instance, is not covered by this investigation. Perceptions of stakeholders such as departments of basic education in provinces and their views are crucial in informing further alignment of the curriculum for science teacher education and training.

As it is indicated in the findings, this study identified gaps in what science curriculum structure expects of science teacher knowledge and the curriculum structure, and delivery for science teacher education and training. It is recommended that pre-service teacher educators in science education departments forge links in the form of professional learning committees (PLC) with all stakeholders (departmental officials from the DBE, the DHET, school principals, student representatives, alumni) to discuss openly the scope of subject content knowledge and share views about transforming science education at universities and schools. This engagement could in a way attend to students' loud call for the decolonisation of science education, namely for socially, culturally, and historically authentic and authenticated curricula.

Figure 3 below demonstrates the conceptualisation of knowledge integration that this study recommends for the knowledge construction and pedagogy in the broad field of sciences, which could enable pre-service teachers to teach natural science in Senior Phase classes.

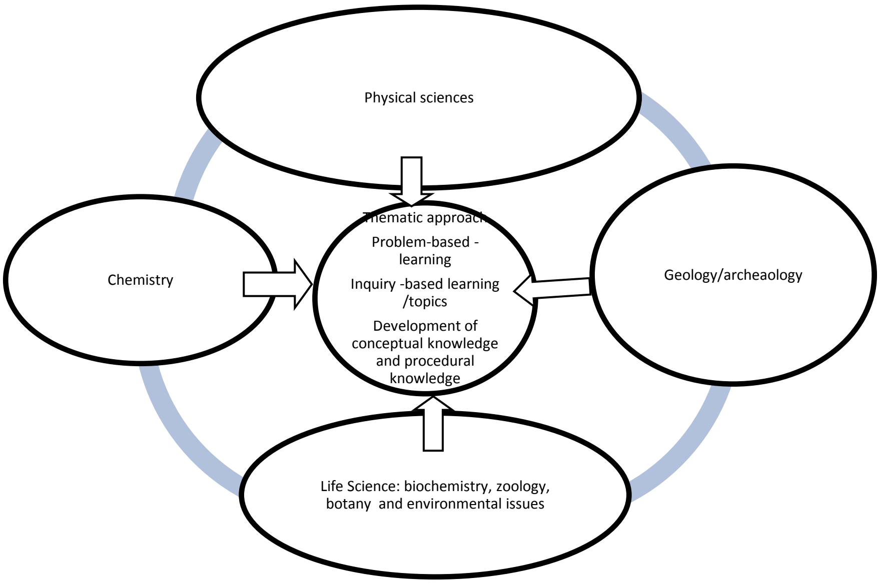

Figure 3 Knowledge integration for the broad-field curriculum based on the ideas of Fogarty (1991) and Luckett (2009)

Authors' Contributions

MK wrote the manuscript and provided data for Tables 1, 2, 3 and 4. KB collected documents from universities and conducted interviews. Both authors analysed data. KB generated the diagrams and figures. Both authors reviewed the final manuscript.

Notes

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