Professional Development in Environmental and Sustainability Education
Voices, Practices and Reflections of Science Teachers

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Abstract

A specialised multi-pronged approach is necessary in order for environmental and sustainability content knowledge to be integrated into the Science curriculum. This underscores the need for Science teachers to be innovative in their teaching, and to be supported through professional development. This study aims to explore how professional development at a tertiary institution can be used to support practising Science teachers in curriculum innovation when they teach environmental and sustainability education in the new Curriculum Assessment Policy Statement (CAPS) curriculum. A qualitative approach is adopted in this interpretivist study. The sample comprises ten purposefully selected Science teachers who registered for a Bachelor of Education Honours programme. Drawing on constructs from the Zone of Feasible Innovation (ZFI), which is related to Vygotsky's Zone of Proximal Development (ZPD), practising Science teachers' engagement in curriculum innovation in environmental and sustainability education is analysed. Data were generated using reflective journals, lesson plans, and interviews. The findings suggest that teachers experience challenges related to 'the how' and 'the what' of implementation of environmental education concepts enshrined in the CAPS document. Insights into teacher agency (in terms of content knowledge, teaching strategies and assessment) which catalysed teacher transformation, are presented. The implications of the findings will be significant for education department officials involved in teacher professional development, teacher education institutions, and school teachers themselves.

Keywords: Curriculum innovation, environmental and sustainability education, professional development.

Introduction

> 'Environmental education (EE) is hard to understand for me even as a teacher … I was not sure how to explain it to learners' (Life Sciences Teacher 3)

> 'Previously I rushed through the section on environmental and sustainability education just to get through it' (Life Sciences Teacher 9)

The preceding quotes from interviews and reflective journals of practising Life Sciences teachers give credence to the views of Reddy (2011), and Dreyer and Loubser (2014), that although efforts have been made to integrate environmental education into the formal curriculum, its implementation remains problematic. Rogan and Aldous (2005) contend that the reason for this is that the focus has been on the *what*, instead of the *how*, of curriculum implementation. They assert that the capacity of teachers to implement curricula needs more attention, and is not an automatic process. The preceding diary reflections of Teachers 3 and 9, which relate to teaching environmental and sustainability education, attest to this lack of capacity to implement the curriculum.

In this paper, we bring to the centre the views and practices of Life Sciences and Natural Sciences teachers when they teach environmental and sustainability education. We argue that in order for teachers to understand and implement changing curricula, they need to be innovative. We focus on the following research question: How do Science teachers who have engaged in professional development activities enact the curriculum by innovating in environmental and sustainability education?

We begin with a review of the South African school context, where, paradoxically, a consistent feature has been the topic of curriculum change (Reddy, 2011; Rogan, 2007, 2015). This is followed by explicating the connectedness between curriculum change and innovation, and a rationale for focusing on curriculum innovation. Theoretical constructs from the Zone of Feasible Innovation (ZFI) and Zone of Proximal Development (ZPD) are justified and these are linked to subsequent sections on the methodology, professional development (PD), and findings and the conclusion.

Changing curricula in South Africa

After 1994, which ushered in a new democratic order in South Africa, political change and economic redress were emphasised, and a transformed education system was seen as crucial to achieve these goals, which were underpinned by a social justice discourse (Reddy, 2011). Educational reform was based on liberatory ideologies and was implemented rapidly. Curriculum 2005 (C2005) was formulated, underpinned by an outcomes-based education (OBE) approach, which signalled a major shift in teaching and learning between pre- and post-apartheid dispensations in South Africa.

Intensive focus on policy, and less focus on implementation often characterises efforts towards education reform, and this was no different during the post-1994 era in South Africa (Rogan, 2007). To this end, Rogan (2007, 2015) points out that it is crucial for curriculum policy to take into account achievable strategies for implementation within realistic time frames and actual contexts. C2005, however, was not based on a deep consideration of the diverse school contexts in South Africa (Rogan, 2015). The learner-centred pedagogy at the core of C2005 was aimed at reducing 'elitism, and the dominance of the white, male orientation in the curriculum' (Hoadley & Jansen, 2009: 174). A social reconstructionist ideology was intended which focused on education for the empowerment of historically disadvantaged people, was relevant to the lives of learners, and would produce scientifically and technologically literate citizens who were capable of critical thinking (Hoadley & Jansen, 2012). The competence curriculum model

characterised the policy design of C2005 because strong links were made between everyday knowledge and school knowledge. Responsibility for the selection of content, sequencing and pacing was devolved to schools. In this way, the democratic order in South Africa sought to influence education for emancipation.

According to Hoadley and Jansen (2012) under-specification of what should be taught, how it should be taught, and what learners should know at the end of each grade created colossal challenges in the implementation of C2005. Rogan (2007) adds that the adoption of C2005 did not consider the capacities of teachers and contexts of schools. Inadequate teacher and school preparation to enable implementation of a 'new' curriculum through OBE, which enshrined reform ideals, paradoxically deepened the disadvantage experienced by schools in underprivileged settings, and advanced opportunities for success in historically advantaged schools (Tshiredo, 2013). Implementation challenges were linked to the highly complex language used to write the policy, inadequate resources and support for teachers and schools, the inability of teachers to use existing support materials, and a shortage of teacher training personnel. Unrealistic time frames for implementation as well as inadequate monitoring and poor in-service teacher training resulted in poor orientation to C2005 (Chisolm, 2005).

Multiple revisions of the curriculum occurred (from C2005 to the National Curriculum Statement [NCS] to the Revised National Curriculum Statement [RNCS] and presently, the NCS-CAPS). The NCS-CAPS was implemented in 2012. The CAPS curriculum is based on a performance model and the content to be taught, as well as methods to be used, sequencing and pacing, which are all, to a great extent, centrally controlled by the Department of Basic Education (DBE).

The ongoing curriculum reform has been marked by subject changes, for example, Biology was replaced by Life Sciences. One aim of the Life Sciences curriculum is to 'use Science and technology effectively and critically showing responsibility towards the environment' (DBE, 2011:8). Three specific aims are central to this curriculum, the third one focuses on applying scientific knowledge responsibly by considering its effect on the environment. A key purpose for studying Life Sciences is to promote responsible actions towards the environment (DBE, 2011). The content includes environmental studies as one of four knowledge strands, and comprises studies of biospheres, biomes, ecosystems, biodiversity, population ecology and human impact on the environment.

Change and innovation

Environmental education is located within a specific knowledge strand – environmental studies – in the CAPS curriculum, and this represents a change from previous curricula. We concur with Rogan (2015) that in order for teachers to implement changes in curricula, they should be enabled to navigate beyond their familiar boundaries of practice to adopt innovative strategies. We argue that the Science teacher's capacity for innovating is crucial for two reasons. First, innovating in Science education has the potential to enable teachers to adapt to changing curricula. Second, the dynamism of innovating in Science education has the potential to enable teachers to teach more meaningfully (Aleixandre & Santamaría, 2007). The renewal of the curriculum design and its associated practices involves curriculum innovation, which

is characterised by the intersecting influences of research, policy and practices (Williamson & Payton, 2009).

The etymology of curriculum reveals its Latin origin in the word *currere*, which means 'to run' (Van Laren, Mudaly, Singh, Mitchell and Pithouse-Morgan, 2012). The dynamism associated with 'curriculum' results in a change from the noun (a course to be run) to a verb (to run) (Van Laren *et al.*, 2012). Curriculum is therefore conceptualised as ever-moving, ever-evolving. The etymology of 'innovate' reveals it roots in the Latin *innovare*, which means to make new, or to renew (Van Laren *et al.*, 2012). The concept of curriculum innovating is therefore central to this paper because it subsumes ideas of change, renewal, evolution, all within a dynamic context.

A focus on theoretical underpinnings related to curriculum innovation, Vygotsky's ZPD, and how these define the nature of Rogan's ZFI is appropriate. In this paper, the concept *curriculum* is rooted in the social reconstruction ideology. Inequalities which are rooted in socio-historical categories, and which influence teaching and learning contexts in diverse school settings, need to be considered when curriculum renewal is enacted. We argue that the *what* and *how* of curriculum implementation is contingent on a multitude of factors, and we focus on professional development as a means of facilitating the realisation of the intended curriculum.

Curriculum innovating

In order for teaching to remain relevant, curriculum innovating is essential (Ferrari, Cachia & Punie, 2009). Although the view that curriculum innovating must be at the forefront in Science education is widely held, Kirkgöz (2007) and Kärkkäinen (2012) caution against adopting an over-optimistic expectation of this process by illuminating challenges associated with innovation. They contend that curriculum innovating is contingent on factors associated with school contexts, different qualities of teacher training and experience, the presence or absence of support, and the quality and availability of resources such as text books. If Science curriculum innovating is to be sustained, the capacity of research organisations and school systems needs to be enhanced (Fishman & Krajcik, 2003). It is crucial to place the teacher at the centre of the complex process of curriculum innovating (Lamie, 2004). According to Emo (2009), teacher-initiated and teacher-driven innovation is under-researched. Reddy (2011) adds that the pedagogy, as it relates to the teacher who teaches environmental education, needs to be explored. We address this paucity by focusing on how teachers engage in curriculum innovation when they teach about the environmental and sustainability, by tapping into teachers' ZFI.

Honing in on the Zone of Feasible Innovation (ZFI)

The ZFI (Figure 1) refers to innovative teaching strategies which transcend boundaries of current practice, but which are doable and sustainable, within the prevailing school context in terms of material and human resources and the school ethos (Rogan, 2007).

Figure 1. The location of the ZFI on a continuum

Source: Rogan, 2007:450.

Departing from routine practices into the ZFI depends on 'teacher factors, learner factors, physical factors and school management/ethos' (Rogan, 2015:5). Altinyelken (2010) asserts that the physical infrastructure and material resources of the school determine the school's capacity to innovate. She asserts that a well-managed school under visionary leadership can influence a teacher's motivation and capacity for innovation positively. Factors which support innovation by teaches include: commitment, willingness to adapt to or lead change, willingness to collaborate, excellent content knowledge, and qualification for the subject (Rogan & Aldous, 2005). Responsible, self-regulating, independent learners who willingly attempt new ways of learning and who are fluent in the language of instruction, can contribute to curriculum innovating, according to Rogan and Aldous (2005).

Rogan (2015:6-9) mentions four steps involved in the construction of the ZFI. First is the designing of a continuum by school personnel, which takes into consideration existing internal and external elements (e.g. national curriculum policy, what is deliverable by the school) which favour curriculum implementation. Second, school personnel consider the available resources within and outside of the school, then plan the sequence of implementation on the continuum. Subject matter and school context are carefully examined to consider how the teacher can adapt or improvise, given the prevailing resource allocation. Third, school-based managers focus on where current teacher practice is located on the continuum, and what innovation is possible in the immediate future, given the school context. Individuals tasked with implementing innovative strategies are selected, and the extent of the implementation in terms of the boundaries of the ZFI are identified. Plans are made to obtain support from other schools which have implemented new teaching strategies successfully. In the fourth and final step, implementation within the ZFI takes place. Teachers in the same district can work together and test ideas related to curriculum innovating, and this can facilitate social learning. This social learning is embedded in theoretical constructs from Vygotsky's ZPD which underpin the ZFI (Rogan, 2015).

Vygotsky emphasised the importance of the social environment in the learning process. He contended that logical thinking is initiated and enabled by members in a group setting. According to Vygotsky, more knowledgeable others assist children in progressing beyond the existing ability level, thereby moving them into the ZPD. They then appropriate the knowledge, which was first acquired in a social setting (inter-psychological), as their own (intra-psychological). Vygotsky's ZPD overlaps with Rogan's ZFI because both can apply to teacher learning which occurs during professional development. Moving into the ZPD

or ZFI involves moving into an experimental stage of learning en route to internalising the practice or concept. Motivation to move into the ZFI involves a willingness to experiment with curriculum innovating and to incorporate successful innovations into one's own practice. This motivation could be rooted in professional satisfaction (internal factor) or the pressure to comply with policy (external factor) (Rogan, 2007:446).

Rogan's positioning of the teacher as a learner is different from the way Vygotsky conceptualised the learner. Rogan (2007) asserts that when one positions the teacher as a learner within a workshop setting, one needs to be cognisant that the teacher, unlike the lead expert, is responsible for actually implementing the curriculum. In Vygotsky's ZPD, the more capable other (e.g. the expert/adult teacher) is largely responsible for the learning which takes place; while in the ZFI, the choice of appropriate innovation is the responsibility of the teacher, even when the teacher is positioned as a learner within the workshop. While the ZPD focuses on 'appropriateness of new conceptual material' which, although they are new to the learner, are within the learner's cognitive reach, the ZFI focuses on 'appropriateness of innovative practice' which can be implemented within a particular context (Rogan, 2007:248). A practice cannot be implemented without cognitive understanding in the ZFI. Therefore, Rogan (2007) contends that moving into the ZPD and/or the ZFI is contingent on cognitive development, and in this paper, we examine the role of professional development in moving teachers into the ZPD and ZFI.

Methodology

A qualitative methodological paradigm was employed in order to obtain an in-depth understanding of how teachers could be supported to innovate in environmental and sustainability education. Ten purposefully selected teachers, out of a class of 32, formed the case to be studied. The criteria for their selection were that they should have been practising Life Sciences or Natural Sciences teachers, and were enrolled to study the Curriculum Development in Mathematics and Science Education module, which was one out of eight modules in the Bachelor of Education Honours programme. Multiple data generation methods, including document analysis, individual interviews, photo narratives and reflective journaling, were used. For the purpose of this paper, the following data sets were analysed: reflective journals, individual interviews and lesson plan documents.

The teachers were given five tasks (presented in Appendix 1), which were sourced or adapted from the article by Rogan and Aldous (2005) and from materials generated for the Fundisa for Change programme.[1]

The teachers' responses to the tasks were summarised in portfolios of evidence. The ten teacher participants were interviewed about their practices, and they recorded their experiences related to innovating in environmental and sustainability education in reflective journals over a period of ten months.

Each of the teachers was fully qualified to teach Life Sciences and/or Natural Sciences. The participants taught in diverse socio-economic settings and, with the exception of P6 and P9, each teacher had less than ten years of teaching experience.

Table 1. Profiles of participants

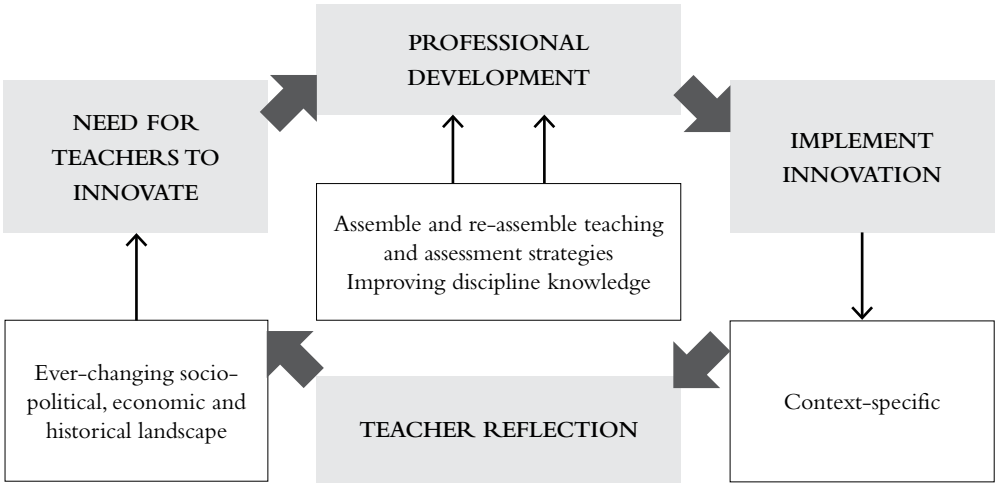
	Race	Gender	Subjects currently teaching	No. of years teaching Life Sciences and or Natural Sciences	Type of area which school serves
P1	African	Female	Life Sciences and Natural Sciences	3	Middle-class socio-economic community.
P2	Indian	Female	Life Sciences and Natural Sciences	2	Lower to middle-class socio-economic community. Some learners come from townships.
P3	African	Male	Information Technology and Natural Sciences	1½	Lower socio-economic community. Most learners come from townships and underprivileged backgrounds.
P4	Indian	Female	Life Sciences and Natural Sciences	8	Lower to middle-class socio-economic community. Some learners come from townships and underprivileged backgrounds.
P5	Indian	Female	Life Sciences and English	1	Lower to middle-class socio-economic community. Some learners come from townships and surrounding area.
P6	African	Female	Physical Sciences and Natural Sciences	19	Lower socio-economic community. Most learners come from townships and underprivileged backgrounds.
P7	African	Male	Physical Sciences and Natural Sciences	3	Affluent community.
P8	Indian	Male	Natural Sciences and Life Sciences	1	Lower to middle-class socio-economic community. Some learners come from townships and underprivileged backgrounds.
P9	Indian	Male	Natural Sciences and Physical Sciences	25	Lower to middle-class socio-economic community. Some learners come from townships and underprivileged backgrounds.
P10	Indian	Male	Natural Sciences and Mathematics	7	Lower to middle-class socio-economic community. Some learners come from townships and underprivileged backgrounds.

The connectedness among theoretical constructs, methods and methodology is important to show how this particular kind of PD promoted opportunities for teachers to advance into the ZFI and ZPD.

Professional development: Translating theory into practice

We adapted Tytler, Symington and Smith's (2011) constructs of PD to create a model (Figure 2). We also borrowed from Frost's (2012) criteria for PD as an engine for active curriculum innovation – as opposed to being a vehicle for passive curriculum implementation – to inform our analysis of the PD module activities (Tasks 1 to 5 in Appendix 1).

Figure 2. Authors' model illustrating the key features of curriculum innovation



Source: Adapted from constructs from Tytler *et al.*, 2011.

Teachers' willingness to innovate is crucial when new curricula are implemented (Chee, Mehrotra & Ong, 2014). We posit that teachers' belief in the need to innovate is a factor which can motivate teachers to innovate. This was achieved in the PD module by engaging teachers in the reading and group discussion of an article (Tasks 1 and 2). Deep thinking in a social environment was enhanced in this way, and this strategy was informed by Vygotsky's contention about the value of learning in group settings (Rogan, 2015). The PD module required that teachers appraise their context closely (Tytler, 2009) in order to determine what change is feasible and realisable (Task 3). The teachers were encouraged to be professionally accountable (Frost, 2012) by improving their content knowledge through research (Task 4). Based on their knowledge about innovation, their enhanced knowledge about their school context and their enhanced disciplinary knowledge, teachers planned lessons with assessment activities (Task 5.1). They were expected to have their lesson plans reviewed by a senior colleague, and revise them based on the review. This was informed by constructs from both the ZPD and ZFI. The senior teacher played the role of 'expert' (ZPD), and assisted teachers by enhancing their knowledge of pedagogy and content. Teachers also engaged in deepening their pedagogical and content knowledge independently in order to move into the ZFI. In this way, teachers were active agents in their own PD (Gulamhussein, 2013), as they were requested to revise their lesson plans (move into ZPD and ZFI) and implement the lessons (Task 5.4). Finally, they reflected

on their lessons (Task 5.5) with a view to improving future teaching, based on the support that they could leverage (ZFI). At each stage, teachers were encouraged to 'assemble and re-assemble teaching and assessment strategies (Tytler *et al.*, 2011).

Findings

Content analysis of interview transcripts, reflective diaries and lesson plans resulted in the emergence of two themes, namely:

- Challenges teachers had experienced when they had taught environmental and sustainability education, before engaging in the Honours module.
- Changes in teachers' attitudes and practices after they had studied the Honours module.

The following abbreviations are used:

P participant
II individual interview
RJ reflective journal

Challenges in the classroom

The participants experienced four key challenges when teaching environmental and sustainability education:

- Lack of content and pedagogical knowledge;
- Ineffective professional development by the DBE;
- Lack of support from school management; and
- Inadequate teaching resources.

Table 2: Challenges experienced by Science teachers in the classroom (before they engaged in the Honours programme).

Themes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lack of content knowledge and knowledge of teaching strategies/ methods to successfully teach environmental and sustainability education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ineffective professional development provided by Department of Basic Education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lack of support from school management	×	✓	×	×	×	×	×	×	✓	✓
Lack of resources in school	×	✓	×	×	×	✓	×	×	✓	✓

✓ Indicates that the participant experienced that theme as a challenge.
X Indicates that the participant did not experience that theme as a challenge.

Lack of content and pedagogical knowledge

Regardless of their teaching experience, which ranged from one year to 25 years, each participant indicated in their reflective journals that they felt lacking in the pedagogical practices related to teaching environmental and sustainability education, and the following excerpts provide evidence to this effect:

- 'I did not know how to teach EE before the professional development' (P1 – RJ)
- 'To teach it is hard, I struggled to find a method that simplified the concepts for learners to understand' (P10 – RJ)

The following individual interview responses corroborate views expressed in the journals:

- 'Teaching it was really challenging because the textbooks were not clear … they have examples that are hard for learners to relate to' (P7 – II)
- 'I was not confident teaching environmental and sustainability education to learners because I did not have any method to make it easy for them' (P9 – II)

The rapidly changing curricula from C2005, to the Revised National Curriculum Framework, to the CAPS, was accompanied by a change in teacher education programmes. It is possible that there was *inattention* to environmental education (Fein, 1991), or a *lack* of environmental education (Lotz & Robottom, 1998) or a *neglect* of environmental education (Lotz-Sisitka, 2011) in teacher education programmes, which resulted in teachers being unable to understand environmental education. These factors could also have contributed to teachers' inability to use apposite teaching strategies to facilitate teaching and learning. An unconfident teacher of environmental and sustainable education is problematic, and needs the attention of relevant stakeholders. The inability of teachers to understand environmental and sustainability education limits their conceptual frameworks for dominant social discourses (Lotz-Sisitka, 2011). Teachers' lack of conceptual depth has 'implications for pedagogical content knowledge' (Lotz-Sisitka, 2011: 32).

Ineffective professional development

All the teachers in this study had attended professional development workshops hosted by the DBE. These teachers decried the effects of these workshops on their knowledge and practices by articulating the following evaluations of workshops in individual interviews:

- 'I have been for once-off workshops that are really not worth my time' (P2 – II)
- 'Many workshops I have been for never start on time and the facilitator just reads the CAPS document to us' (P4 – II)
- 'I've been for the workshop but I got nothing on how to teach concepts' (P5 – II)
- 'Going for workshops are sometimes a waste of my time because I lose out on teaching time and don't even gain anything useful' (P8 – II)

These opinions were endorsed by the following journal entries:

- 'Once-off workshops never gave me anything to help me to teach … they just read through the CAPS document' (P4 – RJ)

- 'Just going for two hours for a workshop can't really help me to be a better teacher all it does is give me more work when I get back to school to catch up syllabus. If I learnt something useful then I would not mind' (P9 – RJ)
- 'The workshops never taught me anything and I lost out on time to teach … I asked my HOD not to ask me to go for the next workshop' (P10 – RJ)

Teacher participants understood that short workshops could not serve to remedy their inadequate content knowledge or pedagogical knowledge. Their frustration about the workshops not being 'worth their time' and retarding their coverage of syllabus was possibly aggravated by the poor organisation of workshops and poor preparedness of the facilitators. Insufficient teacher training and ineffective in-service professional development by the DBE has been well documented (Nkosi, 2012; Bertram, 2012; Reddy, 2011; Lotz-Sisitka, 2011).

Lack of support from school management

In the experiences of three out of ten participants, the challenge of teaching environmental and sustainability education effectively was exacerbated by the lack of support from members of the school management. Individual interview responses to this effect included the following:

- 'My HOD doesn't like young teachers giving ideas or new ways to teach so I am reluctant to ask questions or give suggestions' (P2 – II)
- 'My HOD is not very approachable he just wants the work to be completed his way … if I could ask for help I would' (P9 – II)
- 'The school management is not interested in the way we teach … I would appreciate help' (P10 –II)

These were buttressed by the following journal entries:

- 'because my HOD is not helpful I just teach it without any help' (P2 – RJ)
- 'It's hard but I don't have support from the management … some help when I am stuck would benefit my teaching' (P10 – RJ)

Except for two participants (P6 and P9), all the teachers in this study had less than ten years of teaching experience. It is expected that novice teachers would have received mentorship and other forms of support, and this seemed to be the case in most of the participants' experiences. However, in the case of the three teachers who indicated otherwise, the structural domination of school managers constrained their agency.

Inadequate teaching resources

Four out of ten participants indicated that they experienced a lack of resources at their respective schools. This lack of resources had a direct impacted on these participants' efforts to be innovative when they taught environmental and sustainability education. These individual interview responses attest to this:

- At my school we don't have enough textbooks, learners share between three sometimes … (P6 – II)
- We can't run out worksheets for learners due to a lack of funds (P9 – II)
- Textbooks are an issue, sometimes the diagrams are wrong or the notes do not make sense (P10 – II)

The above responses are affirmed by the subsequent journal entries:

- Teaching without worksheets is difficult because drawing and writing notes is time consuming (P6 – RJ)
- Learners share textbooks so teaching is slow and difficult. One textbook was unclear … (P9 – RJ)

Two of the four participants felt severely constrained by the lack of resources. However, the other two participants (P2 and P6) who also experienced a lack of resources at their schools viewed this challenge as a stepping stone towards curriculum implementation. The following responses which emerged from individual interviews attest to this:

- Even though we are not a well-resourced school, I go out and get my own resources; I borrow, make my own and sometimes even purchase my own resources (P2 – II)
- I am in an under-resourced school but I try to get my own resources. I borrow from other teachers (P6 – II)

These participants demonstrated their increased capacity to implement the curriculum by creating or acquiring their own resources to assist them in teaching environmental and sustainability education.

Changes in teacher practice after the professional development programme

All participants had engaged in developing units of work and in teaching this work, as part of the Curriculum Development in Science and Mathematics module in the Honours programme. Participants' responses revealed that this activity (developing and teaching unit work) effectively exposed them to ideas for innovative teaching. Table 3 provides a summary of their past and present lesson plans.

Table 3. Summary of previous and current lesson plans

Topic Grade Subject	Past and present teaching practice	Strategies and resources	Source	Teacher input
Greenhouse effect Grade 7 Natural Sciences	Previous strategy	Read from text book. Summarise points.	Prescribed text books	Transmitted information in text book without considering context of learners.
	Present strategy	Learner-centred games. Word-match game. Wordsearch. Word puzzle.	Internet: Global Warming Activity pack	Adapted to suit local context.
		Practical investigation: Observe the Greenhouse effect in a jar.	Franklin Institute Resource for Science Learning	Generated assessment worksheet to assess knowledge of apparatus and method, and skills of observation. Higher-order question included consideration of how the investigation could be improved.
Ecotourism Grade 10 Life Sciences	Previous strategy	Use prescribed learner workbooks. Read and respond to activities.	Prescribed learner workbooks	Facilitated student's reading and check correctness of their answers.
	Present strategy	Group work. Learners read materials about biological control, subterranean life forms, invasive plant species, and impact of humans on biodiversity in South African cities.	Durban Natural Science Museum Environmental Management Department: Ethekwini Municipality	Worksheet was developed to answer questions based on the materials, and to give personal opinions about ecotourism. Poster presentation activity is given about how humans reduce biodiversity in South African cities.
Atmosphere Grade 9 Natural Science	Previous strategy	Run out worksheets or write notes on the chalkboard.	Prescribed text book	Select notes/activities and create or copy worksheets.
	Present strategy	YouTube video: Atmosphere in motion. Stimulate class discussion about dimensions of layer of atmosphere. CBS news item: Stimulate class discussion on effects of greenhouse gasses on the atmosphere, and resultant effect on all life forms. eNCA news clip: Local industries to which students can relate; and the effects of pollution from these industries on the atmosphere.	Internet	Group task was designed where learners had to work collaboratively to research how humans impact the local environment negatively, and present their findings using pictures and graphs.

A marked shift from past to present teacher preparation and practice is evident in the table. For their present lessons, teachers developed original resources, engaged learners in collaborative learning through group discussions, and tapped into learners' creative abilities by requiring them to develop and present posters. They acquired resources from places used for outdoor learning, such as museums and municipal offices, and gave legitimacy to learners' views by seeking their opinions on human impact on biodiversity; in this way, they created context-specific learning opportunities. Some teachers used YouTube videos and current news clips to teach socially relevant environmental education. They acquired resources from the internet to created entertaining learning games. Teachers also adapted resources from internationally acclaimed institutes (such as the Franklin Institute for Science Learning).

Participants were interviewed about their lessons which they planned and taught as part of the Honours module requirement, and they provided the following views about the module:

> It has positively impacted on my teaching… I feel renewed… I feel rejuvenated. I was caught in the rut of just teaching without concern for learners, but now I changed and motivated to encourage learning. (P4 – II)

When probed for specific aspects of the module which made her feel rejuvenated, P4 said:

> I became aware of other ways of teaching environmental and sustainability education. I did not have the relevant knowledge and skills required to be an innovative teacher but the lectures (in the module) and the lessons I taught on innovation changed that.

On how the module activities enabled innovative practice, P2 asserted:

> I felt as though the activity on the innovative lesson really renewed the way I was teaching environmental and sustainability education. To actually see how one can be innovative in their teaching really gave me a lot of confidence to try and be innovative myself. I learnt something new and this was incredible for me. It was a liberating experience for me. The activities made me come out of my shell and be more creative and critical in my thinking. I believe this was something that I needed, even though I did not know I needed it. (P2 – II)

Other participants expressed the following views:

> Planning and teaching an innovative lesson really exposed me to the idea of teaching using innovation. The lesson I taught was exciting for the learners so that rejuvenated my teaching. (P7 – II)

> I was empowered by the knowledge that I gained from the module. I gained new methods of teaching and strategies from other teachers in the module, to increase learner involvement in lessons. I feel that it is important to include all learners in a lesson and now I have the tools to do this. (P9 – II)

Participants' responses expressed a renewed desire and confidence to teach environmental and sustainability education. They learned from other teachers' presentations in the module, and appropriated some of the ideas as their own. The participants revealed that, for the lessons they had to plan and teach, innovation was the catalyst for their rejuvenated and renewed attitudes towards teaching environmental and sustainability education. This was affirmed by their journal entries.

This renewed confidence, motivation and feeling of empowerment for participants came directly from the fact that they were exposed to new knowledge regarding innovation. The above-mentioned responses of participants indicate that, previously, they had little or no knowledge of how to be innovative. This speaks directly to the effectiveness of the professional development modules. These participants experienced challenges (lack of confidence/motivation) that required effective professional development. This correlates with Singh's (2011) assertion that effective professional development should address the individual, contextual needs of a teacher.

Closely associated to the increased confidence and motivation of participants is the transformation in planning and teaching practice. The subsequent responses emerged from the individual interviews:

> I feel transformed by the fact that I have new knowledge and different methods to help me teach now. Previously I did not have too many methods, but now I know that with some creativity I can teach environmental and sustainability lessons that learners benefit from. (P1 – II)

> This professional development enabled me to think and practice different ways to teach Natural Sciences. (P3 – II)

Participants were asked about what triggered their transformation, and they offered the following insights:

> What triggered a transformation in me was that I had knowledge of innovation in the form of notes and I also had experience of teaching an innovative lesson. I know that it works and learners enjoy it and learn, so I feel that it was what triggered a transformation in me. I realised that my old ways of teaching would not work anymore. (P3 – II)

> I feel as though I have transformed as a teacher … The positive responses of the learners triggered a transformation in me. Even the quiet ones in the class are now participating in the lesson. (P5 – II)

> Learners' participating in the lesson and showing me that they are learning. I am transformed knowing that I can teach using exciting and attractive activities for learners to understand better. Some learners never used to participate in the lesson and now they do. (P7 – II)

These journal entries affirms the above responses:

> I was bored using the textbook and notebook, to teach now I feel transformed in the classroom. (P8 – RJ)

> I find that you naturally have it in you to be innovative, but all you need is the support or the push to do it. This honours module was actually a catalyst for my change. (P1 – RJ)

A majority of responses from participants indicated that the source of transformation for them was the positive responses of their learners to their innovative teaching methods. From this it is evident that the response of the learner to a new teaching style is critical for the teacher to adopt and/or sustain the practice. This concurs with Guskey's (2002) assertion that when a teacher implements a new teaching method in the classroom, it is the performance of the learners that determine whether or not the teacher espouses the new teaching methods as practice.

Discussion

The need for teachers' professional development to underscore subject knowledge and pedagogical content knowledge in environmental and sustainability education has been widely documented (Lotz-Sisitka, 2011; Mifsud, 2012; Reddy, 2011). The professional development module in this study provided teachers with the opportunity to learn by deepening and widening the scope of their knowledge, attitudes and skills, and creating the space for them to improve their professional competence in environmental and sustainability education. The newness of their teaching strategies energised them; it boosted their confidence in their ability to teach, it was 'incredible' and 'liberating'. It awakened their creative potential and capacity for critical thinking and changed their practice. The teachers engaged learners in activities which made them excited to learn and participate, and encouraged previously passive learners to become involved in knowledge construction.

Teachers in this study progressed from existing practices to new, innovative practices. The entire school was not involved in this study's curriculum innovation, therefore the steps from constructing the continuum to implementing the ZFI were not engaged with by all the stakeholders. Three teachers did not enjoy the benefit of enabling managers, and their views remind one of the negative consequences of 'managerial postures opposed to teachers' work' (Lea, 2012:41).

An examination of teacher factors reveals that each teacher was fully qualified to teach Science, and each teacher had had in-service teacher professional development. The teachers were dissatisfied with professional teacher development programmes offered by the DBE. They viewed their professional growth from the Honours module more positively, and indicated that it resulted in their 'coming out of their shell'. Some teachers believed that their schools were poorly resourced because they could not access printed material. However, when they engaged in curriculum innovating, they obtained materials from other sources, such as museums. They also used digital information to create their own resources or to use directly in their teaching.

These actions suggest that teachers progressed beyond the boundaries of current practice into the ZPI.

Conclusion

The findings in this study reveal that a professional development module was effective because it created opportunities for teachers to become self-regulating by providing them with strategies to actively research topics and deepen their disciplinary knowledge. The module also promoted the value of innovation in Science education. Drawing on constructs from the ZFI, teachers engaged in a conscious examination of their school context as these relate to teacher factors, learner factors, physical resources, school management and school ethos. This information provided them with the knowledge of how they could teach innovatively by using existing resources, or leveraging resources using different methods. They valued the critique of their lessons from more knowledgeable teachers and revised their plans to teach. Social learning was enhanced when they presented their lessons to their peers who were also studying the module. They shared their ideas and incorporated teaching strategie learned from their peers into their own practice. The professional development module created space for experimentation, sharing, constructive critique from others, and deep, critical self-reflection on one's own practice. This generated transformational learning; it cultivated courage to do things differently, and culminated in transformed practice. Teachers' confidence in their own potential to be effective practitioners in environmental and sustainability education soared. Their enthusiasm to teach innovatively was bolstered by a renewed sense of epistemic credibility, and they planned to sustain their practices because learners participated more actively and shared in their teachers' excitement. Teachers' conscious choice to learn new ways of teaching contributes positively to the implementation of a reformed curriculum, and can address the call for learners to 'acquire knowledge and skills needed to promote sustainable development' (UNESCO, 2015:vi), through professional development.

Notes on the Contributors

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Endnote

1. The Fundisa for Change Programme prepares teachers to enhance their knowledge in environmental and sustainability education, as this relates to content knowledge, pedagogical knowledge and assessment. The programme was initiated by members of the Environmental Learning Research Centre at Rhodes University in Grahamstown, South Africa.

References

Aleixandre, M.P.A. & Santamaría, F.E. (2007). Innovation in science education – Turning kids on to science. http://www.kidsinnScience.eu/upload/file/244265_kidsINNScience_Deliverable_D4-1_101126.pdf, visited on 16 January 2017.

Altinyelken, H.K. (2010). Curriculum change in Uganda: Teacher perspectives on the new thematic curriculum. *International Journal of Educational Development*, 30, 151–161.

Bertram, C. (2012). What does research say about teacher learning and teacher knowledge? Implications for professional developement in South Africa. *Journal of Education*, 52, 3–26.

Chee, Y.S., Mehrotra, S. & Ong, J.C. (2014). Professional development for scaling pedagogical innovation in the context of game-based learning: Teacher identity as cornerstone in 'shifting' practice. http://dx.doi.org/10.1080/1359866x.2014.962484, visited on 17 January 2017. pp.1–22.

Chisholm, L. (2005). The politics of curriculum review and revision in South Africa in regional context. *Human Science Research Council of South Africa*, 35(1), 79–100.

Department of Basic Education (DBE). (2011). *NCS Curriculum and Assessment Policy Statement for Life Sciences*. South Africa: Department of Basic Education.

Dreyer, J. & Loubser, C.P. (2014). Curriculum development, teaching and learning for the environment. In C.P. Loubser (Ed.), *Environmental Education and Education for Sustainability. Some South African Perspectives*. Pretoria: Van Schaik. pp.145–177.

Emo, W. (2009). Teachers who Initiate Curriculum Innovations: Motivations and benefits. Unpublished Doctoral thesis, Department of Education, University of York.

Fein, J. (1991). Accepting the dual challenge for professional development in environmental education. *International Journal of Environmental Education and Information*, 10(1), 1–17.

Ferrari, A., Cachia, R. & Punie, Y. (2009). *Innovation and creativity in education and training in the EU member states: Fostering creative learning and supporting innovative teaching.* Luxembourg: Institute for Prospective Technological Studies. pp.1–54.

Fishman, B.J. & Krajcik, J. (2003). What does it mean to create sustainable science curriculum innovations? A commentary. *Science Education*, 87, 564–573.

Frost, D. (2012). From professional development to system change: Teacher leadership and innovation. *Professional Development in Education*, 38(2), 205–227.

Gulamhussein, A. (2013). *Teaching the teachers: Effective professional development in an era of high stakes accountability*. http://www.centerforpubliceducation.org/Main-Menu/Staffingstudents/Teaching-the-Teachers-Effective-Professional-Development-in-an-Era-of-High-Stakes-Accountability/Teaching-the-Teachers-Full-Report.pdf, visited on 17 January 2017. pp.1–44.

Guskey, T.R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and*

Practice, 8(3), 381–391.

Hoadley, U. & Jansen, J. (2009). *SAIDE Curriculum Organizing Knowledge for the Classroom* (2nd edn). Cape Town: Oxford University Press Southern Africa (Pty) Ltd.

Hoadley, U. & Jansen, J. (2012). *SAIDE curriculum organizing knowledge for the classroom* (3rd edn). Cape Town: Oxford University Press Southern Africa (Pty) Ltd.

Kärkkäinen, K (2012). Bringing about curriculum innovations: Implicit approaches in the OECD area, OECD. http://dx.doi.org/10.1787/5k95qw8xzl8s-en, visited on 17 January 2017.

Kirkgöz, Y. (2008). A case study of teachers' implementation of curriculum innovation in English language teaching in Turkish primary education. *Teaching and Teacher Education*, 24, 1859–1875.

Lamie, J.M. (2004). Presenting a model of change. *Language Teaching Research*, 8(2), 115–142.

Lea, Y. (2012). The praxis of mentoring: Power, organising and emancipation. *Journal of Teacher Education for Sustainability*, 14(1), 39–51.

Lotz-Sisitka, H. (2011). National case study – Teacher professional development with an education for sustainable development focus in South Africa: Development of a network, curriculum framework and resources for teacher education. *Southern African Journal of Environmental Education*, 28, 30–71.

Lotz, H. & Robottom, I. (1998). Environment as text: initial insights into some implications for professional development in environmental education. *Southern African Journal of Environmental Education*, 18, 19–28.

Misfud, M. (2012). Environmental education development in Malta: A contextual study of the events that have shaped the development of environmental education in Malta. *Journal of Teacher Education for Sustainability*, 14(1), 52–66.

Nkosi, B. (2012, 17 August). Teachers unprepared for curriculum. *Mail and Guardian*. pp.1–3.

Reddy, C. (2011). Inaugural address – Environmental education and teacher development: engaging a dual curriculum challenge. *Southern African Journal of Environmental Education*, 28, 9–29.

Rogan, J.M. & Aldous, C.M. (2005). Relationships between the constructs of a theory of curriculum implementation. *Journal of Research in Science Teaching,* 42(3), 313–336.

Rogan, J.M. (2007). How much curriculum change is appropriate? Defining a zone of feasible innovation. *Science Education*, 91(3), 439–460.

Rogan, J.M. (2015). Unfinished business: From policy to implementation. Keynote address presented at the International Council for Education on Teaching (ICET) in Tokushima.

Singh, S.K. (2011). The role of staff development in the professional development of teachers: Implications for in-service training. *South African Journal of Higher Education*, 25(8), 1626–1638.

Tshiredo, L.L. (2013). The impact of the curriculum change in the teaching and learning of Science: A case study in under-resourced schools in Vhembe District. Unpublished Masters thesis, Department of Education, University of South Africa, South Africa.

Tytler, R. (2009). School innovation in science: Improving science teaching and learning in Australian schools. *International Journal of Science Education*, 31(13), 1777–1809.

Tytler, R., Symington, D. & Smith, C. (2011). A curriculum innovation framework for science, technology and mathematics education. *Research in Science Education*, 41, 19–38.

UNESCO. (2015). Education 2030 Incheon Declaration and Framework for Action Report.

Van Laren, L., Mudaly, R., Singh, S., Mitchell, C. & Pithouse-Morgan, K. (2012). Exploring university educators' lived experiences of curriculum innovation through integrating HIV and AIDS. *Alternation*, 19(2), 138–161.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. London: Harvard University Press.

Williamson, B. & Payton, S. (2009). *Curriculum and teaching innovation: Transforming classroom practice and personalisation*. United Kingdom: Futurelab.

Appendix

The following information was given to the teachers in the PD module:

South African teachers have experienced numerous planned educational changes during the past two decades. Designing and implementing curricula are complex tasks. In this assessment task, you are required to interrogate policy documents and design a unit of work based on biodiversity (Life Sciences) or climate change (Natural Sciences). The unit needs to be reviewed by a peer. The curriculum must then be implemented and recorded using photo-narratives. The planning and implementation must be analysed.

Task 1: Read the following article by Rogan and Aldous (2005) 'Relationships between the constructs of a theory and curriculum implementation' in *Journal of Research in Science Teaching*, 42, 3. pp. 313-336.

Task 2: Engage in a class discussion of profiles of implementation, capacity to innovate and outside influences, which are three central constructs in Rogan's ZFI. These examples apply to Science education.

Task 3: Getting to know your context, your school and students.

1. Briefly describe your school in terms of its population of learners, number of learners doing Life/Natural Sciences, academic performance in the subject.
2. Refer to Appendix B, Table 2 (Rogan & Aldous table which shows profile of implementation, capacity to innovate and outside influences). Describe current learner factors, school management and ethos, physical resources, and teacher factors which are related to innovation in learning.

Task 4: Deepening your subject content knowledge.
Information research: Select a key concept which relates to biodiversity (Life Sciences) or climate change (Natural Sciences) from the CAPS curriculum. Find at least two resources (e.g. textbooks, internet, field guides, journals, newspapers, periodicals) to extend your knowledge of biodiversity/climate change. Complete an analysis of the two resources.

Task 5: Plan and improve your teaching practice.

5.1. Plan two lessons to address the specific topic you have researched. Include realistic strategies which would make your lesson more innovative. Ensure that you select methods appropriate to the concepts, skills and values that are included in CAPS and which are relevant to learning. Include an assessment activity in your plan.
5.2. Ask a senior teacher to review your plan and to write a report on your plan.
5.3. Revise your lesson plan based on the report.
5.4. Implement your lesson plan. Take four photographs which show significant moments related to innovation. Provide a description of the teaching/learning interactions for each photograph.
5.5. Reflect on the activities you have described. Describe how you could improve on the activities for each lesson. Explain how elements in Task 3.2, could change to support the improvement you envisage.