Mainstreaming ESD into Science Teacher Education Courses:
A Case for ESD Pedagogical Content Knowledge and Learning as Connection

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Abstract

In this case study, researchers evaluated national education policies in Zambia, analysed a localised science (Chemistry 5070) syllabus, assessed a university teaching methods course, and evaluated 54 mathematics and science education students' perceptions on mainstreaming education for sustainable development (ESD) into their courses. ESD was a salient matter in education policies and in the preamble to Chemistry 5070, but not in the university teaching methods course. The chemistry syllabus included ESD issues in the 'notes' section, but was lacking in guidance on teaching and learning approaches to integrate the issues. The university Teaching Methods course did not include content and methods to assist teachers to effectively teach Chemistry 5070 and to integrate ESD issues into it. Students surveyed had some awareness of ESD issues and most were inclined to suggest that ESD issues must be mainstreamed into their courses, especially in educational theory courses; few students suggested natural sciences as carrier subjects for ESD. The findings pointed to a discrepancy among educational policies, school Chemistry 5070 and the university teaching methods courses. A paradigm shift is recommended in order that the quality and relevance of science education be viewed via the metaphor of 'learning as connection' and that Shulman's (1986) pedagogical content knowledge model be adapted so that content and pedagogy of science courses are inclusive of social and humanistic issues such as those advocated in ESD discourse.

Introduction

Science educators have struggled for decades with the question of how to design and evaluate curricula so that scientific knowledge does not end up in isolated, artificial settings such as tests, but leaves sustainable traces in students' daily lives (Van Eijck & Roth, 2007). This observation foregrounds the important concern for quality and relevance in science education, especially the need to connect its teaching and learning to issues in the real lives of learners. With reference to this, the Ahmadabad Declaration proposed that education must build capacity in order to engage critically with contemporary (unsustainable) discourses and practices (ICEE, 2007). It suggested that transformation in pedagogy is also needed in science education where, by historical precedent, the focus has been on the technical side of learning that lacks personal and/or societal relevance (Yager, 2002). In this article, we examine the question of the quality and relevance of science education by mainstreaming ESD. We evaluate the policy context, the curriculum context, and the perceptions of pre-service teachers mainstreaming ESD in the context of mathematics and science teacher education. This is a local response to an international call. For example, we note three actions at the level of practice in the Bonn

Declaration (UNESCO, 2009) of relevance to this research:

1. Support the incorporation of sustainable-development issues through the development of effective pedagogical approaches, teacher education, teaching practice, curricula, learning materials, etc.;
2. Reorient curriculum and teacher education programmes in order to integrate ESD; and
3. Promote evidence-informed policy dialogue on ESD, drawing upon relevant research, monitoring and evaluation strategies, and the sharing and recognition of good practices.

The findings of this study are interpreted in the light of the metaphor 'learning as connection' (Lotz-Sisitka, 2010) and by reflecting on Shulman's (1986) pedagogical content knowledge (PCK) model. Learning as connection implies learning that has meaning in people's lives (Lotz-Sisitka, 2010; Stephens, 2003), while PCK interweaves pedagogy and subject matter knowledge for good teaching of the subject. This is a viable way of describing the knowledge possessed by expert teachers (Veal & MaKinster, 1999). The notion of learning as connection conflates with concepts of inclusivity (Lotz-Sisitka, 2010) and with 'bigger issues of society' such as democracy, freedom, equality and human rights, or, conversely, exploitation, oppression and inequality (Stephens, 2003). For Lotz-Sisitka, learning as connection implies 'to be inclusive of culture, local context and issues and practices that have meaning for local societies such as environment and sustainability practices, health education practices, life skills and citizenship practices' (Lotz-Sisitka, 2010:26). These issues are the ones often excluded from science education, and, yet, they can provide a context for relevance and personalisation of meaning.

To connect the learning of sciences to these and other sustainable-development issues requires a reconsideration of what constitutes the PCK of science teachers. We therefore suggest that the traditional models of school science may exclude attention to ESD and the context of learning the science. The Johnstone (1991 & 2006) model was developed in the context of the learning of the technical assets of the discipline, that is, its macroscopic, sub-microscopic and symbolic representation. In the case of chemistry, explanation of the behaviour of substances is in terms of the abstract world of atomic theory and representing that behaviour in terms of chemical equations, mathematical equations, graphs, reaction mechanisms, analogies, et cetera. The PCK of the teacher developed around this model of learning a science, we conjecture, leads to abstraction and to fixation on the technical and symbolic representation of science concepts, theories and models (Bucat, 2004; Bond-Robinson, 2005; Hofstein, 2005) at the expense of personal and societal relevance. As such, it fails to connect, for the majority of learners, the chemistry of substance to students' life-world of environmental pollution and impact (atmospheric, soil, water and public health) or sustainable-development issues of human rights.

We contend that the PCK (Shulman, 1986) modelled around the Johnstone (1991) model of learning science would focus mainly on the knowledge about the teaching and learning of particular subject matter. It accounts for the particular learning demands inherent in the subject matter (Bucat, 2004) and thus excludes matters of societal relevance, for example responsible citizenship and sustainable development. This is the sense in which we interpret Geddis (1993) (in Bucat, 2004) who states that '*many of the pedagogical skills of the outstanding teacher are content-*

specific' (emphasis added). We suggest that the competencies of the teacher must include a clear understanding of the connection of this specific science content to societal issues and a clear appreciation of the pedagogy in order to communicate this connection to societal issues such as those defined in ESD. Mainstreaming ESD thus requires us to reflect critically on these two models (Shulman, 1986; Johnstone, 1991 & 2006) through which science education is practised in terms of the context and pedagogy for learning. The Ahmadabad Declaration (ICEE, 2007), for example, reminds and urges us to change our thinking about education and learning and to employ approaches suited to integrating environmental education (EE)/ESD principles and for transformative learning in all areas of the curriculum, that is, science education included.

Purpose and Significance of the Research

This vision of the Ahmadabad Declaration (ICEE, 2007) predicates learning science in context, which entails addressing personal needs, addressing societal issues, and orienting learners for science–technology-related careers (Yager, 2002). Yager (2002) makes the point that '*context* – rather than *content and process skills* – is essential for learning science' (emphasis added). 'Science in context' implies 'learning as connection', thus making it feasible for students to connect their learning to real life. In real life, reality is defined by the impact of science and technology on society, for example global warming, climate change, et cetera. Real understanding of science, therefore, is a real-world context for seeing, learning and using the ideas and skills which develop when emphasis is given to questions, problems, concerns and societal issues (Yager, 2002:3) and when there are opportunities for reciprocation of learning between school and community (Shumba, Kasembe, Mukundu & Muzenda, 2008). Yager cites studies that showed that, in the United States of America (USA), 85 to 90% of university science and engineering majors failed to demonstrate real understanding of the concepts and processes they had mastered in courses, when doing their independent research. The students could not use the information and skills to solve problems and were unable to connect the ideas and skills to anything else.

> They were merely conscientious students who committed important concepts and skills (often mathematical equations) to memory. In fact, the minds of most of the science and engineering students in the study were not engaged (Yager, 2002:3).

Contextualisation, for example by integrating ESD, enables learners to make a connection of the abstract symbolic and technical aspects of science to existing experiences based on the real-world life in the community and in society. It is on the score of contextualisation that the localisation of science curricula in southern Africa is relatively ineffectual. Lotz-Sisitka (2010:24) made this observation with respect to southern Africa, in which she criticised the education systems for 'outdated syllabi and forms of pedagogy offered in foreign languages, or content that is decontexualised and disembedded from local history, experience, culture and aspiration'. In Zambia, for example, the National Assessment Project (1999) pointed to 'a nation at risk', as 'very little learning of the *type expected by society* is occurring in Zambia's schools' (emphasis added) (Examinations Council of Zambia, 2000:6). Localisation of the school science curricula has not led to the desired status with respect to quality and relevance, that is, if one considers the critique of the high-school curriculum in *Educating the nation* (Republic of Zambia, 2005). The authors of *Educating the nation* observed that the 'high school curriculum has no relevance to either the world of work or to the socio-economic realities in the country' and that the pedagogy was examination-driven and characterised by 'parroting and memorisation'. They suggested curriculum reconceptualisation to start with, reflecting on the question 'learning for what?' vis-à-vis real-life situations. In the research reported here, one of our students, in reflecting on participation in this action research, stated:

> AM: One thing I have noted is that, when it comes to learning in Zambia, mostly when we learn, we cram facts mostly up to grade 12. That is always the case. What I am able to see is a situation where we are introducing something [i.e. integrating ESD] which is going to bring a real life situation to … certain lessons, not only just to cram the stated facts and to reproduce the facts but to understand the concepts fully so that they can be of use, even of use to society (Focus Group Discussion, 26 August 2011).

The purpose of this study was:

1. To evaluate how mainstreaming ESD into university mathematics and science education courses improves their quality and relevance; and
2. To explore how mainstreaming may be achieved for the university science teacher education course to have impact and relevance in respect of high-school science education.

Before this could be done, we carried out a policy and curriculum analysis and assessed perceptions of pre-service mathematics and science teachers, guided by two research questions:

1. How are ESD issues featured, or not featured, in national education policies, in a localised science (Chemistry 5070) syllabus, and in a university teaching methods course?
2. What are mathematics and science education students' perceptions on mainstreaming ESD into their university courses?

Methodology

The case study was conducted at the Copperbelt University in Zambia where 54 students in the third year of the Bachelor of Science (Mathematics and Science Education) degree were participants. The degree prepares teachers for high-school subjects in mathematics and the natural sciences through: (a) 10 mathematics and science courses; (b) 6 education theory and practice courses; and (c) 2 research courses – educational research methods and a research project. The students were in the third year of their studies and were taking Teaching Methods (TM310) to prepare them to teach high-school Chemistry 5070. A questionnaire survey and focus-group interviews were conducted to determine the students' perspectives on mainstreaming ESD into their courses.

Results

Analysis of educational policy context: ESD a salient issue?

A review of the educational policy context was conducted with a view to assessing how ESD and quality and relevance issues were featured. We established that the educational framework, *Educating our future* (Republic of Zambia, 1996), permeates all subsequent educational planning policies, including: *Educating the nation* (Republic of Zambia, 2005), the *Fifth national development plan (2006–2010)* (Republic of Zambia, 2006), and the *Sixth national development plan (2011–2015)* (Republic of Zambia, 2010). *Educating our future* informed the localisation of the high-school science curricula, focusing on relevance and diversification (CDC, 2000). Appreciation of the relation between scientific thought, action and technology and the sustenance of quality of life, tolerance and valuing other people's liberties, rights and views, and participating in preserving ecosystems in one's immediate and distant environments is its stated goal. Increasing equitable access to quality education and skills training to enhance human capacity for sustainable national development continues to be the national vision (Republic of Zambia, 2010).

The inclination of *Educating our future* towards ESD is reflected in the themes of the basic education curriculum, for example education for democracy, for peace and for international understanding, education for an occupation, health and personal well-being, and sexuality and personal relationships. The high-school curriculum is expected to prepare learners for 'the conclusion of life in school and for the commencement of adult life' (Republic of Zambia, 1996:60) and for appreciating the:

> … nature of democracy in Zambia, participation in civil life, respect for the personal and sexual integrity of others, maintaining human and personal well-being, managing personal interests and interpersonal relationships, crucial demographic and population control issues, respect for the environment, understanding of the pervasiveness, causes, and human dimensions of poverty, and the positive use of leisure (Republic of Zambia, 1996:56).

All in all, ESD issues are a salient feature of the educational policy scene in Zambia, with the aim being to improve quality, contextualisation, and the relevance of education to national sustainable development. In *Educating the nation* (Republic of Zambia, 2005), it is stressed: 'In order to produce the kind of learner as espoused in the Policy, one would have to *place curriculum relevance in the centre of any learning, teaching or training activity*' (emphasis added). The orientation to localisation and relevance of science and technology subjects is found in the following quote from *Educating our future*: 'The criterion should be the relevance of the material to the environment and to the possible later sphere of employment of the people' (Republic of Zambia, 1996:35).

Analysis of high-school Chemistry 5070

Chemistry 5070 is a localised science syllabus *that we analysed to check how it reflects or does not reflect educational policy pronouncements and an ESD orientation in its content and methodology*. Its rationale is based on the educational policy, *Educating our future* (Republic of Zambia, 1996), in which its EE/ESD intentions are explicit:

> The syllabus also addresses issues of national concern such as Environmental Education, Gender and Equity, Health Education and HIV/AIDS, Family Life Education, Human Rights, Democracy, Reproductive Health, Population Education, Entrepreneurship and Vocational Skills, Life and Values Education (CDC, 2000:v).

Its aims are specific to:

1. Experimental, investigative and practical aspects of chemistry and to interest, enjoyment, and attitudes relevant to chemistry; and
2. An EE/ESD focus, for example making learners confident citizens who have an interest in, and who care for, the local and global environment.

Learners are expected to appreciate the benefits and disadvantages of chemistry to the individual, the community and the environment.

However, assessment objectives do not balance the learning of chemistry content with learning about EE/ESD issues. For example, out of five objectives relating to knowledge with understanding, only one relates to 'scientific and technological applications with social, economic and environmental relevance' (CDC, 2000:8). The other four relate to chemistry phenomena, theory, and symbolic representation. All seven 7 objectives relating to (a) handling information and solving problems, and (b) experimental skills are silent on the context of learning, that is, no reference is made to social, environmental or economic spheres.

The contents of Chemistry 5070 are organised into thirteen units presented on a three-column spread-sheet specifying content (Column 1), objectives (Column 2) and notes (Column 3). Of these 13 units, only Unit 13: Chemistry, society and the environment is the most directly oriented to an EE/ESD context. Contextualisation to EE/ESD in the other 11 units is indirect, with the teacher being guided to specified issues to 'refer to' or to 'include' in the notes section. For example, in the notes for Unit 9: Metals and Unit 12: Non-metals, teachers are asked to refer to: processing of minerals in Zambia; toxic gases and effluents from factories; the disposal of scrap metal; land degradation due to mining and dumping; common pollutants such as carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen and lead oxides; the dangers of ozone-layer depletion, climate change, the greenhouse effect and skin cancers; effluent in rivers from industries and farms; et cetera. While these notes direct teachers to examples of chemistry in the context of Zambian society and industry, the danger of placing such issues there is that most teachers may not read the notes. Besides, the notes do not clarify the depth of treatment of the reference issues and do not specify the teaching and learning methodology.

The practical syllabus component of 5070 specifies experimental work limited to laboratory qualitative analysis and identification tests for anions, cations and gases. It does not contextualise practical work by suggesting analytic tests to be applied to, for example, domestic chemical products, local foods, and resources such as plants, air, soil and water in the local environment.

Overall, the syllabus is silent on pedagogy that would enable teachers to connect the chemistry content to the EE/ESD 'issues of national concern' indicated in national education policies and in the preface and the notes section of the syllabus.

Reflections on Teaching Methods 310

Teaching Methods (TM 310) is the course that introduces students to the teaching and learning of high-school science subjects, for example Chemistry 5070. It was assessed in relation to pedagogical chemistry knowledge in general, to pedagogy for mainstreaming of ESD into it, and in relation to its relevance for supporting mainstreaming of ESD into teaching of Chemistry 5070. From the 2006/2007 academic year to 2011, the Teaching Methods course underwent four changes. In the 2008/2009 academic year, some ESD issues were incorporated, including students projects and presentations, simulations, debate and value clarification, and action research as some of the teaching methods introduced. In the 2010 academic year, the ESD- and action-oriented approaches introduced in 2009 were no longer featured. From one year to the next, changes introduced were not guided by a systematic focus on issues such as mainstreaming a particular pedagogical orientation or learning style or a focus on PCK. TM 310 tends to focus on general PCK, that is, general strategies for teaching mathematics and science subjects (Veal & MaKinster, 1999). It is silent on domain- or topic-specific PCK (Veal & MaKinster, 1999) and on pedagogy that would enable teachers to connect the chemistry content to the 'issues of national concern' identified in the preface to Chemistry 5070. In our view, TM 310 is currently inadequate in order to provide sound PCK for Chemistry 5070 and to enable teachers of this high-school course to integrate ESD into their teaching of it.

Results of student surveys

A survey, interviews and focus-group discussions were conducted with 54 students (46 males and 8 females) in the third year of the four-year BSc (Mathematics and Science Education). The results presented here are those from the sections of the questionnaire that asked students to assess statements on a Likert-type scale concerning: (a) whether or not there should be integration of sustainable-development (SD) issues into courses; (b) the importance of development knowledge, skills and attitudes for sustainable development, based on the Learning and Skills Council (2010) statements; (c) the importance of teaching and learning approaches proposed in *The ESD lens* (UNESCO, 2010). In addition to indicating their level of agreement on the Likert scale, they were asked to indicate their choice of carrier subject for particular learning outcomes. Ten-member, focus-group interviews were used to complement the data collected through the questionnaire and to follow up and clarify trends in the questionnaire responses.

Excluding the five students who did not indicate their ages and/or teaching subject specialisation, the students were between 19 and 36 years of age (42 students were 25 years of age or younger) and were distributed according to their main teaching subjects as follows: Biology (n = 14; 25.9%), Chemistry (n = 17; 31.5%), Mathematics (n = 12; 22.2%) and Physics (n = 6; 11.1%). Table 1 summarises the responses of the students to the question whether or not sustainable-development issues must be included in their degree courses. More than 75% agreed to the inclusion of sustainable development in the education courses: Teaching Methods, Principles of Education and Research Methods. Their level of agreement decreased to below 69% for the inclusion of sustainable development in science courses, with the least level of agreement for Physics at 48.1%.

Table 1. Students' responses as to whether or not sustainable-development issues must be included in their degree courses

Course	Frequency as a percentage (N = 54)			
	Agreeing	Disagreeing	Others	Missing cases
Teaching Methods	88.9	1.9	1.9	7.4
Principles of Education	83.3	3.8	5.6	7.4
Research Methods	77.8	3.7	11.1	7.4
Biology	68.5	3.8	9.4	18.5
Chemistry	68.5	3.8	7.5	20.4
Physics	48.1	1.9	20.5	25.9
Mathematics	63.0	1.9	16.7	18.5

Note that 'Others' in the table is a combination of those who did not have an opinion and who did not indicate any response, that is, missing cases.

Table 2 correlates their levels of agreement to inclusion in each subject. Significantly positive correlations among levels of agreement for inclusion of sustainable development in Teaching Methods, Research Methods and Principles of Education were obtained, with the degree of association ranging between 16% and 36%. Their rating of agreement for inclusion of sustainable development in Teaching Methods and Research Methods appeared to have no significant relationship to the rating of inclusion in three sciences (except that the Biology rating correlated significantly with research methods). Ratings of inclusion showed a strong positive association accounting for nearly up to 50% among the sciences.

Table 2. Correlations of perceptions relating to inclusion of sustainable-development issues in courses (N = 54)

	COTM	COPE	CORM	COBI	COCH	COPH	COMA
COTM	1						
COPE	.433**	1					
CORM	.475**	.611**	1				
COBI	.082	.390**	.303*	1			
COCH	.192	.356**	.139	.491**	1		
COPH	.263	.368**	.205	.600**	.741**	1	
COMA	.348**	.282*	.001	.349**	.565**	.730**	1

Key: * Correlation is significant at the 0.05 level (two-tailed).

** Correlation is significant at the 0.01 level (two-tailed).

COTM – Teaching Methods; COPE – Principles of Education; CORM – Research Methods; COBI – Biology; COCH – Chemistry; COPH – Physics; COMA – Mathematics

When students were asked to suggest examples of sustainable-development issues to be included in each course, the percentage of those giving a realistic example was as follows: Teaching Methods (59%), Principles of Education (54%), Biology (52%), and Research Methods (50%). Fewer and fewer students suggested examples of sustainable development to be included in Chemistry (44%), Physics (30%) and Mathematics (19%). The most commonly identified issues were: pollution, waste management, global warming and climate change, conservation, gender and intergenerational equity, human rights, and health and population education.

Tables 3 to 5 show the results of the students' perceptions regarding statements to assess level of agreement with respect to inclusion of specific knowledge, skills and attitudinal outcomes in education for sustainable development taken from the Learning and Skills Council (2010) and the UNESCO ESD Lens (2010), with minor modifications. The results are shown in Table 3 (knowledge outcomes), Table 4 (skills) and Table 5 (attitudes), where the two aspects to be read off are the ratings and ranking in importance of each outcome and the proportion of students suggesting a specific subject as a carrier for the outcome. In reading the data on proportion of students suggesting a specific subject as a carrier for the outcome, we allowed a 40% threshold as the level that would reflect a subject as a carrier for the outcome.

Table 3. Pre-service teacher perceptions of the importance of knowledge outcomes in ESD and potential carrier courses

Knowledge of education for sustainable development	Frequency (%) of those rating (N = 54)							
	Importance & rank	Carrier subject						
		TM	PE	RM	CH	PH	BI	MA
K1. Interdependence of society and life on planet	90.7 (1)	27.8	40.7	24.1	24.1	27.8	68.5	18.5
K2. Limited carrying capacity of planet	64.8 (10)	11.1	14.8	16.7	14.8	42.6	29.6	11.1
K3. Value of biological, social and cultural diversity	88.9 (3)	29.6	31.5	25.9	18.5	16.7	74.1	11.1
K4. Role of rights and responsibilities	85.2 (6)	40.7	59.3	40.7	18.5	14.8	13.0	16.7
K5. Role of equity and justice	87.0 (5)	27.2	72.2	35.2	26.7	13.0	11.1	14.8
K6. Observing precautionary principle	81.5 (8)	20.4	37.0	38.9	25.9	37.0	33.3	25.9
K7. Rights of future generations	90.7 (1)	25.9	61.1	29.6	20.4	22.2	27.8	18.5
K8. Democracy and civic participation	85.2 (6)	27.8	50.0	38.9	11.1	9.3	11.1	14.8
K9. Equitable distribution of wealth and resources	70.4 (9)	22.2	46.3	31.5	14.8	13.0	14.8	24.1
K10. Participation in initiatives to eradicate hunger and poverty	88.9 (3)	31.5	46.3	31.5	25.9	18.5	27.8	20.4

Key: TM – Teaching Methods; PE – Principles of Education; RM – Research Methods; CH – Chemistry; PH – Physics; BI – Biology; MA – Mathematics

Table 3 shows that 8 out of 10 knowledge outcomes were rated as important in 80% of the responses. Based on the 40% researcher-determined threshold, 7 of the knowledge outcomes were expected to be carried in Principles of Education. The question of rights and responsibilities was seen as a matter largely for the three education courses. Table 4 shows that 6 skills or competencies were perceived as important by more than 75% of the students. Table 5 shows that 70–85% of students rated all 7 attitudinal outcomes as important. Overall, the survey shows that students were favourably disposed to the inclusion of specific knowledge, skills and attitudinal outcomes in ESD, mainly through education courses as the carriers. Among the natural sciences, only Biology featured as a projected carrier subject, with items relating to interdependence and to diversity being rated by 68% or more.

When asked to rate the teaching and learning approaches proposed for sustainable development (UNESCO, 2010), the results in Table 6 were obtained. Eight approaches were rated important for university courses by at least 75%; the highest ranking was 'teacher-led and student-led educational storytelling, drama, poetry, music or dance to raise relevant sustainable-development issues' (85.2%). The Research Methods course was expected to utilise 9 (or 60%) of the approaches. Using the 40% threshold, only 3 approaches were considered by the students as pertinent for Chemistry or Biology. These pertained to fieldwork and research projects in the community. The lowest-rated approaches were critical media analysis (ranked 15) and the use of multimedia technologies (ranked 14).

Table 4. Pre-service teacher perceptions of the importance of skills in ESD and potential carrier courses

Skills in education for sustainable development	Frequency (%) of those rating (N = 54)							
	Importance & rank	Carrier subject						
		TM	PE	RM	CH	PH	BI	MA
S1. Connecting different issues affecting society	85.2 (1)	46.3	59.3	38.9	24.1	18.5	27.8	24.1
S2. Recognising and solving issues	83.3 (2)	29.6	51.9	48.1	24.1	22.2	27.8	22.2
S3. Cooperation and consensus in decision-making	79.6 (3)	29.6	51.9	50.0	18.5	14.8	16.7	20.4
S4. Cooperation in decision-making in respect of power diversity	75.9 (6)	27.8	59.3	42.6	20.4	18.5	20.4	20.4
S5. Thinking critically beyond making systems and products less unsustainable	77.8 (4)	24.1	51.9	40.7	33.3	24.1	27.8	33.3
S6. Thinking to create sustainable systems and products	77.8 (4)	29.6	50.0	38.9	33.3	25.9	35.2	31.5

Key: TM – Teaching Methods; PE – Principles of Education; RM – Research Methods; CH – Chemistry; PH – Physics; BI – Biology; MA – Mathematics

Table 5. Pre-service teacher perceptions of the importance of attitudinal outcomes in ESD and potential carrier courses

Attitudes in respect of education for sustainable development	Frequency (%) of those rating (N = 54)							
	Importance & rank	Carrier subject						
		TM	PE	RM	CH	PH	BI	MA
A1. Confidence to take positive action	83.3 (2)	48.1	53.7	51.9	24.1	20.4	25.9	24.1
A2. Balancing individual behaviours and responsibilities	85.2 (1)	37.0	59.3	38.9	25.9	22.2	31.5	22.2
A3. Respect for, and being in harmony with, the natural world	79.6 (3)	24.1	63.0	29.6	22.2	24.1	35.2	20.4
A4. Respect for biological, social and cultural diversity	70.4 (6)	40.7	40.7	37.0	16.7	18.5	51.9	18.5
A5. Caring for self, other people, all life and the planet	75.9 (4)	35.2	40.7	35.2	29.6	37.0	46.3	24.1
A6. Cultivating peace and mutual understanding	72.2 (5)	35.2	55.6	25.9	18.5	18.5	18.5	16.7
A7. Promoting equality and empowerment for the less privileged	70.4 (6)	40.7	57.4	35.2	20.4	20.4	20.4	20.4

Key: TM – Teaching Methods; PE – Principles of Education; RM – Research Methods; CH – Chemistry; PH – Physics; BI – Biology; MA – Mathematics

Table 6. Pre-service teacher perceptions of the importance of instructional approaches in ESD and potential carrier courses

Instructional approaches for sustainable development	Frequency (%) of those rating (N = 54)							
	Importance & rank	Carrier subject						
		TM	PE	RM	CH	PH	BI	MA
Classroom exposition on students' research	79.6 (3)	50.0	37.0	59.3	22.2	20.4	22.2	18.5
Use of educational entertainment	85.2 (1)	61.1	48.1	37.0	35.2	29.6	29.6	37.0
Presentation by guest speakers	81.5 (2)	37.0	46.3	38.9	35.2	31.5	35.2	27.8
Student (STS) debates	79.6 (3)	27.8	38.9	46.3	37.0	29.6	31.5	25.9
Experiential learning in local community/environment	79.6 (3)	33.3	25.9	44.4	35.2	33.3	35.2	29.6
Analysis of practical data sources, e.g. photographs, videos, graphs, maps, etc.	75.9 (8)	37.0	25.9	35.2	37.0	38.9	35.2	29.6
Student-inquiry projects	79.6 (3)	40.7	31.5	55.6	37.0	33.3	33.3	31.5
Values clarification on STS issues	72.2 (10)	33.3	38.9	37.0	27.8	29.6	29.6	33.3
Simulation and role play	68.5 (12)	40.7	46.3	22.2	24.1	22.2	22.2	22.2
Future problem and lifestyle analysis and projection	68.5 (12)	25.9	31.5	42.6	42.6	35.2	33.3	33.3
Fieldwork in community/environment	74.1 (9)	31.5	27.8	38.9	44.4	37.0	44.4	25.9
Community-service projects	72.2 (10)	25.9	37.0	50.0	27.8	22.2	31.5	20.4
Critical media analysis	57.4 (15)	22.2	33.3	50.0	16.7	18.5	16.7	16.7
Research projects in local community/environment	77.8 (7)	18.5	29.6	48.1	40.7	18.5	25.9	14.8
Use of multimedia information communication technologies (ICTs), videos, social media, etc.	66.7 (14)	31.5	29.6	42.6	35.2	33.3	29.6	27.8

Key: TM – Teaching Methods; PE – Principles of Education; RM – Research Methods; CH – Chemistry; PH – Physics; BI – Biology; MA – Mathematics

Synthesis and Discussion

This study demonstrates that EE/ESD issues are salient in education policies in Zambia. However, the high-school Chemistry 5070 and the university Teaching Methods (TM 310) syllabi do not carry ESD content and change-oriented teaching and learning approaches. They are unlikely to model integration of ESD issues such as those stated in policies, for example human rights, values education, entrepreneurship, et cetera. One of our students put forward the following analysis (our reflections are italicised):

> HM: In here (*referring to a Mathematics syllabus*), if we were to compare the expectations written by the Permanent Secretary [PS] (*in the preamble to the syllabi*) and the content, the way the syllabus really is laid out, in the syllabus, we are just seeing the content itself, specifying the objectives... (*inaudible*). They (*the syllabi*) do not talk about the expectations of the PS (*for mainstreaming EE/ESD issues*) in the content of the syllabi. We just see dry mathematics, pure mathematics. Even if it's Chemistry (*syllabus*), it's just pure chemistry, inside these syllabi. … We can directly say, there is no 'Zambianness' (*possibly meaning no local relevance and contextualisation*) inside the content because the mathematics that is here (*referring to a Mathematics syllabus*) is … the mathematics which everyone else out there does. … We do not see anything that we can say, yes, OK, this is for us (Focus Group Discussion, 26 August 2011).

Pre-service teachers surveyed expected ESD to be mainstreamed in their courses. Their perception was that ESD knowledge, skills and attitudes were better dealt with in educational theory courses than in mathematics and natural science courses. With respect to mathematics and natural science courses, they expected pedagogical changes to address real-world applications and societal issues. One student teacher observed:

> Student 47: The process of teaching [that is] prominent in universities, where lecturers only present the abstract concepts, makes it difficult for the student to get the context of the concept in real life. This never makes it … sustainable, even when the student can master, through memorisation, the concepts from the abstract point of view. Hence the concepts do not add any value to the students' personal lives (Open-response text).

Overall, the results of policy and curriculum analysis and of the student surveys point to a discrepancy among policies, school science syllabi and the university teaching methods course. Policies stipulate mainstreaming of ESD, but the syllabi do not systematically point out the content and the teaching and learning methods for integrating ESD. Students' experiences and perceptions suggest a disconnect between what they learnt in the past or what they are currently learning and ESD outcomes; they anticipate that integration of ESD would enhance the relevance of their courses. A paradigm shift might occur by adopting the metaphor of 'learning as connection', a notion that connects science to social and humanistic issues such as those advocated in ESD discourse.

However, learning as connection cannot be superficially adopted. It requires a deeper reflection on the competencies expected of science educators and teachers. For example, it is ordinarily accepted that teachers who understand the science subject matter, and who are knowledgeable on the specifics of teaching and learning of specific topics making up the subject matter, possess PCK, that is, pedagogical chemistry knowledge (Bucat, 2004; Bond-Robinson, 2005). Looked at from the perspective of Shulman's (1986) PCK model, this subject matter pedagogical knowledge is often interpreted with respect to the technical aspects and content of the subject. A good example is the presentation of subject matter exclusively on the basis of Johnstone's (1991) model of how scientists view the nature of their discipline, that is, examining macroscopic aspects, explaining these macroscopic aspects using subatomic theory, and representing macroscopic aspects in symbols and equations. These models fall short in connecting science to humanistic, social and personal aspects and to societal issues. Consequently, teachers lack the experiences and competencies to integrate ESD and to use transformative teaching and learning approaches (see, for example, UNESCO, 2009; Rosenberg, O'Donoghue & Olvitt, 2008). Bearing in mind that students' experiences and their thinking exist at the macroscopic level (Bond-Robinson, 2005), transformative learning occurs when there are connections to real-life issues and examples. We therefore suggest that, in addition to describing PCK in terms of subject matter knowledge and pedagogical knowledge, PCK must include ESD knowledge and competencies. Teachers need knowledge of specific sustainable-development issues and the pedagogical approaches to integrate ESD into their teaching; they need ESD issue-specific PCK (ESD PCK). ESD PCK would suggest expertise on the part of the teacher of science to connect its subject matter and concepts to personal and societal issues as defined in ESD discourse.

In the context of Zambia, there are numerous local ESD issues and a favourable educational policy context that could serve to contextualise local high-school science education and science teacher education courses. Deliberate and systematic teaching and learning of such issues may serve not only as the constituents and identifiers of the localised syllabus, but also as the 'connectors' to the real issues of concern to Zambian communities. Contextualisation enables learning as connection to achieve what educational theorists such as David Ausubel and John Dewey called 'meaningful learning'. However, as noted in our analysis, the ESD issues tend to be relegated to the preamble to syllabus 5070 and not explicitly articulated in the content section. There is a need for explicit guidance as to how to integrate and to bring into science education ESD- and change-oriented teaching and learning methods (see, for example, UNESCO, 2009; Rosenberg *et al.*, 2008) in order to connect school learning experiences to life and issues in communities. This creates relevance by creating a fit between the experiences in the local community and school learning (Shumba *et al.*, 2008). We think that science education must focus in a balanced way on science discipline, educational theories and societal issues. We take a cue from De Jong (2005), who suggested that an education in science should develop capabilities to form opinions and make political decisions on science–technology–society issues. We see science education as a knowledge area and a process that is beneficial to society at large, and, as such, it must take its full share of responsibility for educating for sustainability thinking and action. For this to happen, social and humanistic issues in the sustainable-development discourse must not remain on the periphery of science learning. We propose that, for 'learning as connection' to occur, ESD issues and suitable pedagogical approaches must become part of the science PCK.

Conclusion

All in all, the issue of contextualisation and our analytical tool of 'learning as connection' point us towards the need to rethink the way we prepare mathematics and science teachers for school-level teaching. We think that Shulman's (1986) PCK model and Johnstone's (1991 & 2006) model of learning science, for example chemistry, do not focus science educators on integration of societal issues as a necessary component of contextualised learning. Our metaphor of 'learning as connection' gives rise to the need to consider the notion 'ESD pedagogical content knowledge (ESD PCK)' a notion that modestly extends Shulman's (1986). This foregrounds the importance of science teachers understanding sustainable-development issues and ESD concepts, principles and values (i.e. ESD content knowledge) and of the appropriate teaching and learning approaches to interrogate and act on them (i.e. the ESD pedagogy). ESD PCK relates to teacher expertise to connect their subject content and concepts to issues of concern to society's development. While the technical content and concepts of science are universal, what defines a local science syllabus is the extent to which it connects these universal concepts and values to experiences and examples from the local environment and culture. A focus on ESD PCK enables this connection and would enable the teaching and learning of a science subject so that it contributes to developing a sustainability-minded citizen consistent with emerging notions of scientific literacy (Shwartz, Ben-Zvi & Hofstein, 2006). Shwartz *et al.* (2006) contend that chemical literacy, for example, could be described in terms of chemistry in context, entailing using understandings of chemistry in daily life, as consumers of new products and technologies, in decision-making, and in participating in a social debate regarding chemistry-related issues and topics, especially in non-formal frameworks. It is imperative in thinking about ESD PCK and learning as connection to reflect on how learning of science subjects must instigate and catalyse a sense of responsibility and agency for sustainable development. Natural-science subjects must aim to contribute their share to moulding a new generation of citizens who value sustainable development. In the 'action' phase of this research, and as a suggestion for further research by others, these challenges and questions must be explored.

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