International Journal of Education and Development using Information and Communication Technology (IJEDICT), 2010, Vol. 6, Issue 4, pp.27-38.

Pre-service Teachers' use of improvised and virtual laboratory experimentation in Science teaching

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ABSTRACT

This research surveyed 11 purposely sampled Bindura University of Science Education (Zimbabwe) Bachelor of Science Education Honous Part III pre-service science teachers' use of improvised and virtual laboratory experimentation in science teaching. A self-designed four-point Likert scale twenty-item questionnaire was used. SPSS Version 10 was used to analyse data. Frequencies, means, standard deviations and standard error means were used to systematically evaluate variables on pre-service teachers' use of the technological resources. Most pre-service teachers (90.9%) used improvised laboratory experimentation in their teaching. However, although the pre-service teachers knew the value and benefits of virtual experimentation, they did not use the technology in their teaching. The methods course (Pedagogics in Science Teaching) for the pre-service science teachers should be more focused on specific instructional uses of technology and technical skills rather than familiarisation with technology, to effectively integrate technology in their teaching to support student-centred learning.

Keywords*: virtual experimentation, improvised laboratory experimentation, science education, appropriate technologies*

INTRODUCTION

Researchers in science education, for example Driver, Leach, Scott & Wood-Robinson (1994) as cited in Zacharia (2007) have shown that students have difficulties in understanding scientific concepts across all ages and levels. Some students come to science classes with conceptions that differ fundamentally from scientific conceptions in specific domains (Limon & Mason, 2002). Posner, Strike, Hewson & Gertzog (1982) attributed the discrepancy to the fact that students construct their conceptual knowledge about the physical world, interpretations for science terminology, and reasonable explanations for how and why things function, over many years of experience in their everyday world. Prior research (e.g. Piaget, 1985; Carey & Spelke, 1994; Chi, Slotta & deLeeuw, 1994; Vosnadou, 1994) has suggested that conceptual understanding is only accomplished through learning that promotes conceptual change. Piaget (1985) cited in Zacharia (2007) also noted that, in order to foster conceptual change, students have to be confronted with discrepant events that contradict their conceptions and invoke a disequilibrium or cognitive conflict that positions students in a state of reflection and resolution. Discrepant events are one of the most effective science teaching methods that give students meaningful experience. Both laboratory experimentation (Bybee, 2000; Hofstein & Lunetta, 2004) and of virtual experiments such as computer-based simulations (Tao & Gunstone, 1999; Zacharia & Anderson, 2003) can be utilised when using discrepant events to teach science.

Whilst real experimentation with conventional laboratory apparatus and equipment is desired, schools in Zimbabwe like many others in developing countries face challenges of limited resources particularly financial resources for acquiring apparatus and materials for imparting effective and efficient science education. Improvised laboratory experimentation (ILE) has been

used as a panacea to the situation at hand (e.g. Ndirangu, Kathuri, & Mungai, 2003). Improvisation is a pedagogical intervention strategy that teachers may use to address similar situations by being resourceful in the making and use of locally available materials where conventional equipment and or apparatus may be inadequate or not available at all (Inyenga & Tompson, 2002). Low-cost materials produced through improvisation are not an attempt to provide a watered down science education, but low cost in the mentioned sense is highly creative and highly productive, provides opportunities for creativity and development of manipulative abilities and concepts are learnt and internalized by concrete and unspectacular work than proceeding with chalk and teacher talk in teaching science (Pimpro, 2005).
Interactive computer-based simulations could be used as conceptual change learning environments (Hofstein & Lunetta, 1982, 2004; Zacharia &Anderson, 2003). Some researches in science education have been carried out on the impact of real experimentation or virtual experimentation (Zacharia & Anderson, 2003) and the impact of the combination of the two methods has on students' conceptual understanding of science (Zacharia, 2007); the scientific literature lacks studies that investigate pre-service science teachers' use of virtual experimentation and improvised laboratory inquiry-based experimentation as appropriate technologies in science instruction for effective conceptual understanding in science teaching and learning in supporting student-centric methodologies, therefore the focus of this study.

The research focused on pre-service teachers, as Ray (2007) and Chen (2009) noted that teacher education programmes are a reasonable place to start with respect to integrating technology into education. Our research question was:

Do pre-service teachers view and use ILE and VE as appropriate technologies in science education to support student-centred learning?

The pre-service teachers had enrolled for Pedagogics in Science Teaching (PC206) course prior to taking Final Applied Science Education (AS403). The Pedagogics in Science Teaching course exposes the students to knowledge and use of various approaches to science teaching including aspects of management of practical work, educational technology and improvisation in science instruction.

CONCEPTUAL FRAMEWORK

Laboratory inquiry-based experimentation has long played a vital role in science education (Hofstein & Lunetta, 1982, 2004). This is supported by Dewey (1938)'s pragmatist philosophical justification for the need and inclusion of experience in education who argue that knowledge is based on experience and reality is found through interaction of individuals with the environment (Ornstein & Hunkins, 2004). This research looks at the interaction through improvised laboratory work and virtual experimentation. Millar (1991) in Kelly, Brown & Crawford (2000) showed that experiments in school science could be used as a basis for negotiation of meaning, but not as a means for theory testing or falsifying. Millar (1991) in Kelly et al (2000) also recommended that experiments be used in school science as a means of communicating abstract concepts through examples, demonstrating what counts as good (i.e. scientific), and identifying approaches to problem solving. The teachers' role is therefore to cultivate critical thinking (Ornstein & Hunkins, 2004). There is need for engaging learners in physical actions and social negotiations (Kelly et al, 2000) in the learning of science. Laboratory procedures are required than could be written and illustrated in even the most detailed guides or instructions. Written materials were found to be insufficient in providing descriptions of scientific procedures (Kelly et al, 2000). Carlsen (1992) also argued that discourse practices in classroom settings are not only to transmit what is known as science they also model science as a process.

The importance of traditional laboratory teaching involving practical experimentation and hands-on work however has in no way decreased as a result of computerized simulation experiments though considerable pedagogical advantage may also be gained by the integration of ICT tools used in teaching science and technology particularly by integrating virtual laboratories (Scheckler, 2003; Kocijancic & Sullivan, 2002). Classroom use of ICT for teaching science and technology has increased dramatically in recent years and has proved to be effective in a variety of situations (Newton, 1997; Roggers, 1997; Sassi, 2000 and Roggers & Wild, 1994 cited in Kocijancic & Sullivan, 2002). Virtual experimentation provided through interactive computer-based simulations has proven to have a positive impact on students' evolving skills, attitudes and conceptual understanding (de Jong & Njoo, 1992; Tao & Gunstone, 1999; Ronen & Eliahu, 2000; Hsu & Thomas, 2002; Huppert & Lazarowitz, 2002; Zacharia & Anderson, 2003; Zacharia, 2003; de Jong, 2006). This is because there are specific scientific phenomena students normally engage in hands-on activities which are directed towards increasing their understanding and insight of the principles involved which are simulated (Kocijancic & Sullivan, 2002). According to Triona & Klahr (2003) virtual experimentations have many advantages for laboratory instruction which include portability, safety, cost-efficiency, minimization of error, amplification or reduction of temporal and spatial dimensions, and flexible, rapid data displays.

Clark (1994) cited in Zacharia (2007) noted that apart from the popularity and potential advantages of virtual experimentation might contribute to laboratory experimentation, there are also claims that disapprove the use of virtual experimentation on the grounds that it deprive students of experiences that involve concrete hands-on manipulation of physical materials which are essential for learning (Scheckler, 2003; Gunstone & Champagne, 1990). According to Kirschuner & Huisman (1998) science educators typically use virtual experimentation only when: (i) a 'real' laboratory is unavailable, too expensive or to intricate; (ii) the experiment to be conducted is dangerous; (iii) the techniques that are involved are too complex for the students; or there are severe time constraints. Kirschuner & Huisman (1998) also noted that virtual experimentation is regarded 'as a surrogate for "real" laboratories, no one views the virtual experiments as a viable method of experimentation in its own right. Educators and researchers also discriminate against virtual experimentation because they consider that when using virtual experiments, they are asking their students to learn in a fundamentally different way than scientists originally worked on the corresponding issues (Steinberg, 2000). According to Resnick (1998), other researchers claim that it is manipulation, rather than physicality, as such, that may be important aspect of instruction.

Both technologies, virtual experimentation (VE) and improvised laboratory experimentation (ILE) have gained the confidence of many researchers for their contribution to learning and instruction. However, there is no unambiguous evidence of the effectiveness and efficiency of VE (eg. Scheckler, 2003; Jong & Joolingen, 1998 in Zacharia, 2007) and ILE (e.g. Ndirangu, Kathuri, & Mungai, 2003). The ultimate goal would be to take advantage of the potentials of both methods of experimentation in order to maximise the effectiveness of laboratory experimentation (Zacharia & Anderson, 2003). This research take VE and ILE as technologies basing on Rollick (1996)'s definition of technology as cited in Ogunniyi (1998:109) who says:

> *Technology is the human activity that purposefully addresses the satisfaction of human wants/needs via the use of physical means that are extensions of human capabilities. Typically, technology activity involves one or more characteristic processes such as problem solving, enterprise, creativity and is set in the context that invariably involves value and moral laden questions.*

Accordingly, in line with the above, Wikimedia (2010) defines appropriate technology as technology that is designed with special consideration to the environmental, ethical, cultural, social, political, and economical aspects of the community it is intended for. In this research ‘appropriate technology’ means technology used by pre-service teachers to support student-centred learning; means to engage students in active learning activities, as supported by Smith, Rudd & Coghlan (2008).

RESEARCH METHODOLOGY

We purposively sampled for the survey eleven Bachelor of Science Education Honours Part III pre-service teachers (8 Male and 3 Female) from Bindura University of Science Education who were on Final Applied Science Education (teaching practice) during the January-April 2010 school term.

The researchers carried out the survey while were on school attachment supervision and assessment visits, therefore the purposive sampling. Purposive sampling is in which the researcher attempts to obtain sample that appears to him/her to be representative of the population (Tardis, 2010), in this case the eleven sampled were from a total of fourteen pre-service teachers who had enrolled for Pedagogics in Science Teaching (PC206) and were now teaching practice.

The pre-service teachers were on a 12-week long teaching practice and were deployed at secondary schools in and around Mashonaland Central and Harare Metropolitan provinces in Zimbabwe. Since this study involved only eleven participants representing an imbalanced number in terms of gender, subject specialisation areas and purposive rather than random sampling, we have been cautious not to over-generalise the results. This is despite that the selected pre-service teachers represented 78.57% of the pre-service teachers who were on teaching practice during the mentioned period.

Research Instruments

A self-developed 20-item questionnaire with responses on a four-point Likert scale (Strongly agrees, SA=1; Agree, A= 2, Disagree, D=3 and Strongly Disagree, SDA= 4) was used to gather data for the study. Strongly Agree (SA) and Agree (A) were combined to mean agreeing and Disagree (D) and Strongly Disagree (SD) meant disagreement.

The questionnaire was first pilot tested to Part II Bachelor of Science Education pre-service teachers who were not part of the study sample before being administered. Pilot testing afforded the researchers to amend ambiguous statements that they be clearer to the respondents and thereby increasing and safe guarding the validity of the instrument. The questionnaire gathered responses in a standardised way and relatively quick to collect information (Institute for Computer Based Learning, 1999). Items ILE1 to ILE12 and VE13 to VE20 solicited for knowledge and use of improvised and virtual experimentation respectively.Data collected was analysed using Statistical Package for Social Sciences (SPSS) Version 10. Data was presented using descriptive statistics.

To complement the questionnaire responses, in-depth interviews were conducted with the same pre-service teachers to validate questionnaire responses through triangulation. In addressing research ethical issues, the researchers revealed to the respondents what the research is all about and how their anonymity would be preserved. Anonymity usually increases the response rate and more sincere responses are given. It was also made clear why they have been chosen to participate as well as their right to accept, deny or even withdraw from participating in the research (Grey, 2004). All those who participated with informed consent.

RESULTS AND DISCUSSION

A mean score of ≤ 2.00 for each analysed variable meant that pre-service teachers agreed and mean scores >2.00 meant that participants disagreed for their use of ILE and VE.

Pre-service teachers' use of Improvised Laboratory Experimentation

Most pre-service teachers agreed that they usually made their own materials (90.9%; mean=1.73) for teaching when conventional apparatus were not available. Amongst others, some responded during follow-up interviews thus:

> *I usually use waste materials to make apparatus for biology practical lessons for example; I may take used plastic containers for make Petri dishes and for culturing samples. (Pre-service teacher 3)*

> *On the topic of Forces in Physics, in the absence of a force meter, I made one using a hollow plastic barrel and spring which I put inside just for the students to see how it works. (Pre-service teacher 8)*

They also believed that construction of own materials develop a sense of ownership (90.9%; mean=1.64), this is consistent with Pimpro (2005)'s view that science has an inward dimension (the spirit of science); science has to be learned and internalised by solid and unspectacular work. The use of familiar materials and resources that are found in the environment stimulates creativity to use them and builds confidence in experimental work (Pimpro, 2005). Kyle (2006) supports this by saying science education must be contextualised and must be linked to life world experiences of the learners. Teachers' use of technology has also been seen to be influenced by organisational context, in addition to teachers' beliefs and other technology related factors (Clausen, 2007; Hermans, Tondeue, van Braak & Valcke, 2008; Higgins & Spitulnik, 2008; Hu, Clack & Ma, 2003; Lim & Chai, 2008; Schrum, 1999; Tearle, 2003).

The use of improvised apparatus in science teaching could be a panacea since most pre-service teachers (72.72%) indicated that the schools they were attached to during their teaching practice did not have well-equipped laboratories as shown in Table 1. Most schools in developing countries have problems of securing proper science equipment and apparatus since these are very expensive as evidenced by Ndirangu, Kathuri & Mungai (2003)'s research in Kenya.

Pre-service teachers (81.8%) indicated that improvisation equally develops science conceptual understanding during teaching and did rated their students as having enjoyed experimentation by using locally made equipment. Though all the pre-service teachers agreed that, to be able to use improvisation in science teaching requires technical skills on the part of the teacher and that teacher-training courses should include a subject on improvisation of technical skills only 54.54% realised that the Pedagogics in Science Teaching course they had enrolled for prior to their teaching practice prepared them to be able to produce low-cost improvised apparatus. On this issue Chen (2009) suggests that courses on teaching methods for teacher preparation programmes should focus on specific instructional use of technology rather than on familiarising them with technology in general. This result supported by Pimpro (2005) who says, teachers need to be trained in manual and methodical skills to be able to properly use locally available materials in practical work lessons. This is a contextual preparation for pre-service science teachers since most schools in Zimbabwe are in rural areas and therefore, these are their possible employment placements areas after their teacher training course.

Pre-service teachers' use of Virtual Laboratory Experimentation

Six (54.54%) of the surveyed pre-service teachers were deployed in schools where computers were available and 72.72% of them indicated that though computers were available they were not connected to the Internet (see Table 2). Fifty-four and half percent of these science pre-service teachers revealed that CD-ROM based software for science were not available in the schools. This finding is consistent with Bhukuvhani (2007) who found out that some Zimbabwean schools had no subject-specific (e.g. science) software for use by teachers to actively engage their students in active learning of science concepts though computers were available in these schools. According to Chen (2009) research has also shown that access to technology, a supportive school culture, and adequate time for pre-service teachers to explore educational use of technology are essential for successful technology integration. Tondeur, Valcle & van Braak (2008) as cited by Chen (2009:34) also noted that "access does not mean only availability of hardware and software but the appropriate type of technology and programs that support teaching and learning" and Freidhoff (2008) went on to explain 'access to appropriate' as the affordances and constraints of a technological tool need to be carefully considered when the tool is incorporated in the lesson.

The pre-service teachers (90.9%) agreed that virtual experimentation develops and enhances students' science conceptual understanding and also 90.9% agreed that students understood science concepts when virtual experimentation is used. This finding is consistent with the research by Bhukuvhani (2007) that both students and teachers viewed ICT resources as enhancing conceptual understanding in science.

About 73% of the pre-service teachers have used virtual experimentation websites and CD-ROM based software during their studies at university. The pre-service teachers (81.8%) acknowledged that they have knowledge of virtual experimentation. One of them when asked gave the response:

> *I know what virtual experiments are but I have not got chance to used some on my own and in teaching y subject. (Pre-service teacher 11)*

According to Chen & Ferneding (2003) pre-service teachers' perceptions about how teacher education programmes promoted the educational use of ICT were a strong factor influencing their intention and use of technology resources in their practicum. Franklin (2007) also found that teacher preparation was one of few key factors associated with classroom use of technology, implying that curriculum integration of technology into methods courses would influence novice teachers' use of technology in their teaching.

However, a larger number of pre-service teachers (63.6%) indicated that they did not use virtual experimentation in their teaching. Russell, Bebell, O'Dweyer & O'Connor (2003) also noted that although new (pre-service) teachers had higher technology skills than veteran teachers, they did not display higher levels of technology use in the classroom. The finding is consistent with Cuban (2001), Harrison et al (2002), Henning, Robinson, Herring & McDonald (2006) who found out that teachers do not use technology in their teaching or use it effectively despite the availability of hardware and software. Successful integration of technology into teaching therefore, depends not only on access and availability of technology but on how instructors (teachers) accept it and use it (Pajo and Wallace, 2001). OTA (1995) in R-J Chen (2009) confirms that, although most teachers see the value and benefits of technology in education, many do not use technology in their teaching.

CONCLUSIONS

The current research focused on pre-service teachers’ use of improvised and virtual laboratory experimentation in science to support student-centred learning. The study systematically analysed an array of statements to evaluate pre-service teachers’ use of the technological pedagogical innovations and resources.

The pre-service teachers tended to use improvised laboratory experimentation in their teaching. It has emerged that the teaching methods course (Pedagogics in Science Teaching) they enrol for prior to Final Applied Science (teaching practice) tended to familiarise them with technology and therefore should be more focused on specific instructional uses of technology and technical skills to effectively integrate technology in their teaching. This has been evidenced by that most pre-service teachers knew the value and benefits of virtual experimentation but many did not use the technology in their teaching.

Table 1: Pre-service Teachers' use Improvised Laboratory Experimentation, *n*=11

Var.	Statement	*frequencies and (% frequencies)*				Mean	Std Error Mean	Std. Dev.
		SA	A	D	SD			
ILE1	I usually make my own materials	4 (36.4)	6 (54.5)	1 (9.1)		1.73	0.19	0.65
ILE2	Constructing own materials develops sense of ownership	5 (45.5)	5 (45.5)	1 (9.1)		1.64	0.20	0.67
ILE3	Improvising requires technical skills	9 (81.8)	2 (18.2)			1.18	0.12	0.40
ILE4	Improvisation can develop/illustrate important concepts	4 (36.4)	6 (54.5)		1 (9.1)	1.82	0.26	0.87
ILE5	I always carry out experiments/ demonstrations in my teaching	5 (45.5)	4 (36.4)	2 (18.2)		1.73	0.24	0.79
ILE6	Most experiments in my subject area can be done using improvised apparatus/ materials	2 (18.2)	6 (54.5)	3 (27.3)		2.09	0.21	0.70
ILE7	The school has a well equipped science laboratory	2 (18.2)	1 (9.1)	5 (45.5)	3 (27.3)	2.82	0.33	1.08
ILE8	Students enjoy learning using locally made equipment	2 (18.2)	6 (54.5)	3 (27.3)		2.09	0.21	0.70
ILE9	Students understand concepts more readily with experiments using improvised materials	4 (36.4)	6 (54.5)	1 (9.1)		1.73	0.19	0.65
ILE10	Improvisation ensures development of science concepts in absence of conventional apparatus	6 (54.5)	5 (45.5)			1.45	0.16	0.52
ILE11	Teacher-training should include a course/subject on technical skills in improvisation	7 (63.6)	4 (36.4)			1.36	0.15	0.50
ILE12	During my teacher training course, I was trained to produce low-cost apparatus	2 (18.2)	5 (45.5)	4 (36.4)		2.18	0.23	0.75

Table 2: Pre-service Teachers' use of Virtual Laboratory Experimentation, *n*=11

Var.	Statement	*frequencies and (% frequencies)*				Mean	Std Error Mean	Std. Dev.
		SA	A	D	SD			
VE13	I use virtual experiments in my teaching	2 (18.2)	2 (18.2)	6 (54.5)	1 (9.1)	2.55	0.28	0.93
VE14	The school has a computer laboratory/ or some computers	4 (36.4)	2 (18.2)		5 (45.5)	2.55	0.43	1.44
VE15	The computers are connected to the Internet	2 (18.2)	1 (9.1)	1 (9.1)	7 (63.6)	3.18	0.38	1.25
VE16	Science CD-ROM based software are available at school	4 (36.4)	2 (18.2)	1 (9.1)	4 (36.4)	2.45	0.41	1.37
VE17	Virtual experimentation develops or enhances students' science conceptual understating	7 (63.6)	3 (27.3)	1 (9.1)		1.45	0.21	0.69
VE18	I have knowledge of virtual laboratory experimentation	3 (27.3)	6 (54.5)	2 (18.2)		1.91	0.21	0.70
VE19	I have used virtual experimentation websites/CD-ROMs at University	3 (27.3)	5 (45.5)	3 (27.3)		2.0	0.23	0.77
VE20	Students understand science concepts more readily when I use virtual experiments	6 (54.5)	4 (36.4)	1 (9.1)		1.55	0.21	0.69

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