International Journal of Education and Development using Information and Communication Technology (IJEDICT), 2012, Vol. 8, Issue 2, pp. 17-27.

Science practical work instructional technologies and open distance learning in science teacher training: A case study in Zimbabwe

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ABSTRACT

The practical work component offers unique challenges for university science courses. This is even more pertinent in an Open and Distance Learning (ODL) environment like the Bindura University of Science Education's Virtual and Open Distance Learning (VODL) programme. Effective ODL education should be flexible enough to accommodate science disciplines with practical components. The main challenges with practical work in ODL are that students are geographically scattered and that they come from very different educational backgrounds. In spite of these constraints, there is an equivalence motive as justification for compulsory practical work as a means to put degrees and diplomas in science education awarded through ODL programmes on the same level of achievement as those offered conventionally as they should equally develop practical scientific inquiry and problem solving skills. This Case Study evaluates the use of instructional technologies for science practical work, adopting Kumar et al (2005)'s five-stage model. The research revealed that although lecturers place great value on practical work, in practice they prefer using lecture notes and internet downloads more than other instructional technologies. Research participants do not use online tutoring at all though the philosophy of VODL requires the use of such technologies that support student-centred learning.

***Keywords**: Science practical work, science education, open and distance learning, instructional technologies*

INTRODUCTION

Education is a fundamental human right (UNESCO report 2000). This is exactly what Open and distance learning (ODL) programmes have been striving to provide. ODL is an amalgam of two approaches to education that focuses on expanding access to learning and the use of multimodal delivery systems such as technology and printed modules. It is characterized by two factors; - its philosophy, and its use of technology (Chikuya, 2007; Freeman, 2004). Most ODL systems have a philosophy that aims to remove barriers to education and to allow students to study what they want, when they want, and where they want. This philosophy implies that education should be made available to all, regardless of time, place, and age (Freeman, 2004; Rowe, 1994).

In addition to quality assurance, ODL programmes offer flexibility that cannot be matched by conventional programmes. These assurances have been established to the fullest by recent development in e-learning, especially in the context of online learning via the Internet. Non-science-based ODL courses have a longer history compared to science-based ODL courses. In the field of science and engineering, the practical sessions have been conducted by some ODL providers, based on an existing practical model and often by setting up laboratories at the districts' learning centres. However, several constraints and difficulties have been observed in the implementation of science-based practical work.

Incorporating practical work into Distance Education courses is a worldwide challenge that calls for careful planning and creative curriculum development. While most science educators would agree that studying science without any exposure to practical work would result in a rather idiosyncratic qualification (Bennett, Metcalfe, Scanlon, Thomas & Williams, 1995), there has been growing realisation that the laboratory is not the only place in which all the objectives of practical work can be achieved. Consensus is spreading that the benefit students derive from practical work cannot necessarily be measured by the number of hours spent in a laboratory.

Effective ODL education should be flexible enough to accommodate science disciplines with practical components. The main challenges with practical work in ODL are that students are geographically scattered and that they come from very different educational backgrounds (Basson, 2010).

The ODL are mostly adult learners and studying in a second language. But in spite of these constraints, there is an equivalence motive as justification for compulsory practical work as a means to put degrees and diplomas awarded through ODL on the same level of achievement as those awarded through full-time residential studies (Basson, 2010).

The present method is very conventional: it relies heavily on physical laboratories. To evaluate use of instructional technologies for science practical work in science, the researchers adopted Kumar, Subramaniam and Mukherjee (2005) five-stage model in trying to address the following research questions that guided this research:

1. How do lecturers value practical work in science teaching and learning?
2. What instructional technologies are being used for teaching and learning of science through the Virtual and Open Distance Learning programme?
3. What students' support materials are available for the Virtual and Open Distance Learning programme?

The Kumar et al (2005) model reduces the dependency on real laboratories. It offers the possibility of many attractive features including interactive experience that can widen the scope of constructivist learning. Successful implementation can be achieved by following the suggested sequence (Kumar et al 2005).

Stage 1 Interactive CDs

Interactive CDs can feature video clips on science experiments. The students will learn how science experiments are conducted and the general rules of conducting an experiment along with the science observations that are featured. These video clips will also motivate and increase the interest of the students to learn science. The learning experience can be enhanced by introducing pop-up questions and multiple choice questions that probe the students to think and test their understanding. In addition, multimedia can through its power to animate communicate dynamic information more accurately than a diagram, and can help students visualize phenomena that cannot be seen (Bennett & Brennan, 1996).

Stage 2 On-line Tutoring

On-line tutoring using an e-learning platform can also help the learning process and hone critical thinking skills in students through active discussion. It enables tutors and learners to bring the face-to-face classroom into virtual environment. Such activities can generates new ideas and cultivate innovation (Kumar et al 2005).

Stage 3 Virtual Laboratories

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 and 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.

Virtual laboratories and computer simulations have been used (Kennepohl, 2001; Martinez-Jiménez et al., 2003; Baran, Currie & Kennepohl, 2004) to enable learners to gain experience in the use and control of apparatus and instruments without the necessity of having the equipment available.

Zacharia (2007) noted that apart from the popularity and potential advantages that 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 and Huisman (1998) science educators typically use virtual experimentation only when: (i) a ‘real’ laboratory is unavailable, too expensive or too 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 and 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.

Stage 4 Home Experiments or Self-built Experimental Projects

Laboratory inquiry-based experimentation has long played a vital role in science education (Hofstein & Lunetta, 1982, 2004). There is need for engaging learners in physical actions and social negotiations in the learning of science (Kelly et al, 2000).

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.

Home experiments using common household materials and equipment (so-called kitchen chemistry) have been suggested as an alternative to laboratory experiments (Kennepohl, 2000; MacQueen & Thomas, 2009). This may be a suitable approach in introductory science courses.

Improvised laboratory experimentation (ILE) has been a panacea to the situation at hand (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).

Bhukuvhani, Kusure, Munodawafa, Sana and Gwizangwe (2010) and Kumar et al 2005 concur that this can be implemented using simple home experiments and / or low-cost commercial experimental kits. These projects need not be complicated; rather, they should provide students with the opportunity of learning science through experiment. Such projects will be more challenging, interesting and train students to be resourceful.

Stage 5 Laboratory Session

Presently, students are required to perform experiments in the labs and are assessed on the quality of their lab reports. Under this model, students will only need to attend a single practical session. The purpose of this session will be to ascertain what the student has learned during the first four stages. A two-fold assessment system is proposed, a 3-hour practical test where the student is required to submit a report at the end of the experiment, followed by a viva session.

CONTEXT OF STUDY

The Virtual and Open Distance Learning Programme

The Bindura University of Science Education's Virtual and Open Distance Learning (VODL) programme emerged as an institutionally born strategy to satisfy the training needs of prospective science educators. The current training policies and economic challenges on higher education access and delivery system in the country appear to deter many prospective science educators at conventional institutions of higher learning including Bindura University of Science Education. The high rate of brain-drain, mainly of science educators the country is experiencing, has created a critical manpower shortage in schools, colleges and universities (Chetsanga, 2001). Science education is the driver of industrial and technological development (Kyle, 2006) and therefore crucial for the much needed economic turn-around. The current conventional science teacher education delivery system cannot totally cater for the local demand of science educators.

The VODL programme was launched as a pilot project in Mashonaland Central province in August 2010, aiming at providing training of science educators at their 'door-steps' and in the comfort of their work places and homes at affordable cost. Currently the programme runs at three learning centres: Guruve-Mbire Districts (Mushumbi Secondary School), Muzarabani District (St. Alberts Secondary School) and Mount Darwin-Rushinga Districts (Chindunduma I Secondary School). These districts are in remotest parts of the province and were reported to have over 80% of the science teachers either being unqualified or requiring upgrading of their qualifications. (Interview with Mashonaland Central Provincial Education Director, 28 April, 2010).The learning centres were established at secondary schools for the sole reason that they do have basic science laboratory infrastructure. There are plans that the programme be extended to other provinces with similar problems making the scope of the project national.

The VODL programme runs on a special kind of delivery strategy that merges Block Release and ODL methodologies. Lectures are conducted at the learning centres during one month long school holidays whilst examinations are taken at the university's main campus in Bindura at the end of each semester. Two school holidays and the period in between constitute a VODL semester.

Conduct of Science Education programmes

At Bindura University of Science Education, practical work sessions are compulsory for students enrolled in the Diploma in Science Education and Bachelor of Science Education programmes. These programmes are offered both through conventional and VODL modes. Most of the students under the VODL are adult-learners mostly primary school relief teachers, aiming to upgrade themselves to become secondary school teachers. All students take courses in either biology, physics, chemistry or geography or a combination of these subjects. Most of these subjects have courses that have compulsory practical components, which mean that laboratory sessions should be conducted by students on a regular basis. However, unlike the practice for conventional programmes offered at the university, the lab sessions for VODL are carried out at the established learning centres.

RESEARCH METHODOLOGY

The Bindura University of Science Education's Virtual and Open Distance Learning programme was identified for a situational case study. In the case study, views of lecturers on the value of practical work in science education and use of various instructional technologies were surveyed. The purpose of the study is to probe deeply and analyse intensively the VODL programme with a view of gaining insights into the use of instructional technologies (Cohen & Manion, 1994).

The researchers purposively sampled 14 out of 20 lecturers. The research participants taught Biological Sciences, Chemistry, Geography and Physics courses on the VODL programme during the first two semesters. Semester 1 was undertaken from August 2010 to January 2011 and Semester 2 stretched from April 2011 to August 2011. All the research participants hold at least Master's Degree and a teaching qualification. The research participants have been pseudo named L_1, L_2 up to L_{14} for ethical reasons.

A questionnaire, interviews and observations were used to collect data. These methods provided means of triangulation to validate the data collected. A self-developed questionnaire with both closed and open ended questions was used. The questionnaire items were analysed by three experienced lecturers and underwent pilot testing on six lecturers who were not part of the VODL teaching sessions. The questionnaire focused on the value of practical work in science teaching and learning and the use of various practical work instructional technologies for ODL (Interactive CDs/DVDs, Online Tutoring, Fieldwork, Virtual experimentation sites, Practical work sessions and Modules) and teaching. The interviews probed further the lecturers' understanding of the above technologies as they apply to VODL.

An observation guide was used during observations of proceedings as to how practical work was conducted at the learning centres. These observations were done during the teaching blocks between August 2010 and August 2011, and were made possible by the deployment pattern which allowed the researchers to be deployed one at each centre during the research period.

RESULTS AND DISCUSSION

Lecturers' Views on Value of Science Practical Work

All lecturers viewed practical work as an important and integral component of science teaching and learning, as exemplified by some responses:

> *Practices play a paramount role in the teaching and learning of physics courses. They enable students to have a hands-on experience which*

> *reinforces the integration of theory and practice. Students are given a chance to interact with the environment. (L_1)*
>
> *It plays a very pivotal role since it enables application of knowledge gained in real-life situations through innovation and problem solving. (L_4)*

These findings concur with Woodley (2009) and Miller (2004) who posit that good quality practical work can engage students, help them to develop important skills, help them to understand the process of scientific investigation and develop their understanding of concepts as well as acquisition of an understanding of hazards, risk and safe working.

Lecturers' Use of ODL Instructional Technologies for science practical work

The instructional technologies use were analysed using Statistical Package for Social Sciences (SPSS 17). Frequencies of use were rated 0=Not At All, 1=To some extent and 2=Frequently. A mean score of greater or equal to 1 meant the lecturers used the instructional technology and a mean score less than 1 meant they did not use it. Table 1 (Appendix 1) shows frequencies of use of the instructional technologies.

Interactive CDs/DVDs

Only a small number of lecturers (28.6%) used interactive CDs/DVDs to some extent whilst the rest (71.4%) did not at all use these despite the availability of computer laboratories at the learning centres with computers with necessary hardware to read data from CDs/DVDs. The university library also has some science materials on CDs/DVDs. The utilization of this mode of technology could alleviate the problems posed by the non-availability of subject modules as these allow that course materials may be captured, edited and archived to enable future reuse and reference (Kirithivasan et al, 2006).

Online Tutoring

All lecturers mentioned that they are not using online tutoring. This result is substantiated by Kirithivasan, Baru, and Iyer (2006) who assert that online tutoring is not very suitable for distance education in developing countries due to the cost of implementing such technologies and the low levels of penetration of the Personal Computer.

Virtual Experiments

The majority of lecturers (57.1%) do not make use of virtual experiments in their teaching. Only 28.6% and 14.3% of the lecturers indicated that they employ virtual experiments in their teaching to some extent and frequently respectively. On the other hand 57.1% mentioned that they do not use simulations as a practical work strategy in teaching VODL courses whilst 42.9% only make use of simulations to some extent. The non-use of Virtual labs by most lecturers deprives the learners of the advantages offered by Virtual labs in terms of convenience of use and the complementary role they play in practical work in science teaching and learning (Benetazzo, Bertocco, Ferraris, Offelli, Parvis & Piuri 2000).

Home Experiments/ Self-Built Experimental projects

Some of the lecturers (28.6%) do not employ home experiments in their teaching at all whilst 71.4% use them slightly. The lecturers also prepared and used improvised laboratory apparatus and materials (57.1%= to some extent; 28.6%= frequently). The delegation of practical experiments to be done at home needs to be encouraged as it allows teaching to be personalized and allows students to gain experience in tackling practical problems as well as in communicating their results (Heather, Hughes & Edgecombe, 1979).

Fieldwork was not used by 71.4% of the lecturers besides the fact that the environment can be used as a laboratory with naturally occurring phenomena for most science subjects. Some geography lecturers cited transport provision as a hindrance for fieldwork without noticing that the learning centres are located where they need not travel afar for viewing phenomena and studying courses such as Physical Systems of the Environment and Introductions to Physical Geography. They responded thus:

> *Lack of transport to field areas and lack of time for field visits (L_7; L_{10})*

Laboratory Sessions

All the lecturers for the subjects investigated mentioned that all the courses offered by their respective department required some form of practical work to develop science skills. Despite that only 28.6% frequently used practical laboratory sessions whilst 57.7% used the laboratory sessions to some extent. Most lecturers cited some hindrances that prevented them from carrying out practical work as being among others, large classes and limited laboratory resources. Some of them responded thus:

> *Frequent power cuts, inadequate lab equipment to cater for the large numbers of Diploma students (L_{13}).*
>
> *There are limited resources for the large numbers of enrolled students L_3).*
>
> *Classes are too large for the available equipment (L_2).*

ODL Student support Materials

The majority of lecturers (57.1%) do not use modules as support materials for their students learning, only 28.3% use them frequently. This is the scenario despite the fact the ODL programmes should have student support materials such as printed modules and study guides among others (Chikuya, 2007).

CONCLUSIONS AND RECOMMENDATIONS

Lecturers place a lot of importance on practical work as a component for science teaching and learning. The research participants prefer to use lecture notes and internet downloads more frequently followed by practical lab sessions and improvisation. Practical laboratory sessions follow a more traditional approach. Home experiments are also used to some extent. Simulations, modules and virtual experiments are amongst the least used technologies whilst online tutoring is not being used at all.

Lecture notes, handbooks/hand-outs are the major student support materials used by the lecturers whilst modules are the least used technology. This may require that the university expedites the writing of modules as support study material for the students on the VODL programmes. Of great concern is the non-usage of online tutoring considering that the name of the programme has a virtual component to it.

An e-learning platform on the University's website should be created as well as installing Internet facilities at the learning centres through, for example, V-SAT which utilizes satellite technology to overcome the non-availability of a reliable telephone network in the remote districts of the country where the programme has learning centres.

Further research needs to be undertaken on how the VODL learners view the role and structuring of practical work in the learning of science.

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APPENDIX 1

Table 1: *Lecturers' Use of ODL Science Practical Work Instructional Technologies*

Item 4	Statement	*frequencies and (% frequencies)*			Mean	Std. Dev.
		Frequently	To some extent	Not at all		
a	Internet downloads	6(42.9)	8(57.1)	0	1.43	0.514
b	Lecture notes	12(85.7)	2(14.3)	0	1.86	0.363
c	Home Experiments/Self-Built Experimental projects	0	10(71.4)	4(28.6)	0.71	0.469
d	Interactive CDs/DVDs	4(28.6)	0	10(71.4)	0.29	0.469
e	Improvisation	4(28.6)	8(57.1)	2(14.3)	1.14	0.663
f	Virtual Experimentation	2(14.3)	4(28.6)	8(57.1)	0.59	0.756
g	Fieldwork	2(14.3)	2(14.3)	10(71.4)	0.43	0.756
h	Online Tutoring	0	0	14(100)	0	0
i	Practical Laboratory Sessions	4(28.6)	8(57.1)	2(14.3)	1.14	0.663
j	Simulations	0	6(42.9)	8(57.1)	0.43	0.514
k	Modules	2(14.3)	4(28.6)	8(57.1)	0.57	0.560