Science beyond the classrooms and laboratories: An ODL approach

C. E. Ochonogor*
Institute for Science and Technology Education
e-mail: Ochonec@unisa.ac.za

S. J. Mohapi*
College of Education
e-mail: mohapsj@unisa.ac.za
*University of South Africa
Pretoria, South Africa

Abstract

Many people believe that the teaching and learning of science are only achievable in the classroom and, in some cases, the laboratory. This notion has forced many school learners and educators to abandon the teaching and learning of science or to do it haphazardly, while complaining that they lack the materials and human resources. This article examines the teaching of saponification reactions in organic chemistry to undergraduates using special open distance learning (ODL) strategies outside the normal classroom and organised laboratory situation. The strategies used were Skype (a special form of video-conferencing technology) and animation. The teaching involved both theory and practice and on evaluation, the learners proved to be as competent as if they had been taught in contact sessions. The study showed that sciences, such as life science, physical science and related disciplines, can be effectively taught and learnt through the ODL approach in schools, and particularly at university level.

Keywords: animation, Cognitive Theory of Multimedia Learning, exclusion principle, open and distance learning, organic chemistry, saponification, science, Skype

INTRODUCTION

Traditionally, science teaching has been undertaken in laboratories and only in schools which were provided with them. This implied that learners from many schools without adequate and appropriate science equipment and facilities were inadvertently denied the learning and practice of science (Ochonogor 1989, 56). This in turn could have contributed to the age-long shortage of scientists and engineers in the world including South Africa. Ojo, Ogidan and Olakulehin (2009, 2) infer that there was a great need for the nations of the world to seek ways of providing quality education for the majority of their citizens in an equitable and accessible manner, in agreement with Fafunwa (1974, 17). It is regrettable to mention that this dream has remained a challenge due to the over-dependence on the conventional school system that was in place over the centuries across the world. There was also some loss of momentum due to the slow pace in responding to the challenges of the new millennium. Studies have shown an acute depletion of science equipment and facilities and the growth of 'ghost' laboratories in most schools in developing and underdeveloped countries. It is therefore imperative to determine ways of effectively teaching science to a larger number of students with fewer constraints in terms of equipment, facilities and human resources. This is the gap that the open distance learning (ODL) approach is expected to fill by ensuring effective science teaching across the borders and beyond the classroom and school laboratories.

ODL is an innovative teaching/learning approach that focuses on opening access to education and training provisions, freeing learners from the constraints of time and place. It is aimed at offering flexible learning opportunities to individuals and groups of learners. In an attempt to define ODL, Hulsmann (1997, 4–5) identified the following four crucial features characterising the approach:

- Separation of the teacher from the student in time or place or both;
- Use of technical media (various forms of technology) courseware like print, video and audiocassettes, radio and television broadcasts, telecommunications and computer band learning;
- The need for a two-way communications system allowing some level of interactions between tutors and the students in either a synchronous or asynchronous manner exists. This is to minimise passive reception signals usually experienced in broadcasts;
- The necessity for institutional accreditation of programmes and courses based on the influence of the host institution as a matter of policy is also paramount.

In effect, a proper ODL arrangement is expected to provide possibilities for face-to-face tutorial meetings, particularly at the undergraduate level, learner-learner interactions, library study, laboratory and practice session and encouragement for individual study processes (Commonwealth of Learning and the Asian Development Bank 2000, 9–6). This would mean or show that ODL does not just imply total separation of the teacher from the learner but could involve the use of special technologies to give more involving and practical learning experiences to the learners at their own time and in their own space. The ODL approach therefore can be used to achieve the goal of educating and equipping a large population of learners even outside the four walls of educational institutions. The authors of this article devoted time to using the ODL approach in teaching an aspect of science (saponification chemistry), using animation and Skype (a special form of video-conferencing technology), to groups of learners outside the normal classrooms and organised laboratories. They chose this topic and subject in order to determine the effectiveness of the ODL approach particularly as many high schools in South Africa lack the expensive laboratory facilities and equipment that not readily available. In general, the ODL approach demonstrates the following advantages:

- It overcomes the problem of physical distance which learners face to reach the few and distant institutions of learning.
- It helps to solve the problem of time or scheduling for both the teachers and learners.
- It expands the limited number of places available for student placement or admission as against the conventional residential institutions.
- It accommodates low or dispersed student enrolments irrespective of location.
- It makes the best use of the few teachers available in the event of a shortage of qualified, skilled and experienced manpower for effective teaching.
- In fact, the ODL approach potentially deals with the challenges of cultural, religious and political considerations among both the learners and the teachers.
- It deals with gender, race, group and individual differences, and consequently makes learning and education generally affordable to all.

Saponification is generally seen as a process of the reaction of a triglyceride with a strong base, such as sodium hydroxide, to produce soap in organic chemistry. It is the base hydrolysis of triglycerides which are esters of long chain fatty acids to form sodium or potassium salts of the respective carboxylates. The sodium or potassium salt formed is the major product while a second and useful substance called glycerol is also formed as a minor product. A triglycerol or triglyceride ($C_{55}H_{98}O_6$) has a molar mass of 855.37 gmol^{-1} and is an unsaturated long chain fatty acid as shown in Figure 1.

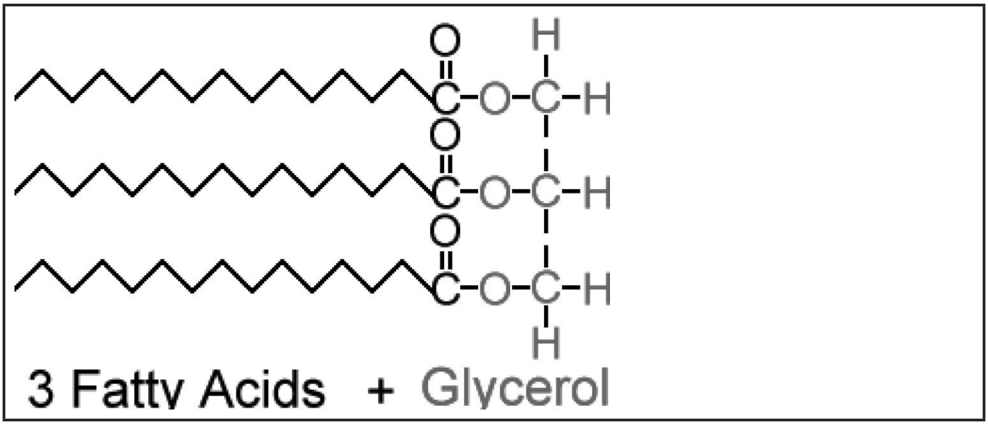

Figure 1: An unsaturated long chain fatty acid

Many other long chain fatty acids are available for saponification reactions, including: palmitic acid (hexadecanoic acid) $C_{16}H_{32}O_2$ with a molar mass of 356.42 gmol^{-1}, which is an example of saturated plant fatty acid (red palm oil); and Oleic acid $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$, which is a monounsaturated omega-9 fatty acid with a *molar mass* of *282.4614 gmol*$^{-1}$ found in various animal and vegetable fats in nature. Other saponification plant oils or fatty acids are avocado oil, coconut oil, castor oil, olive oil, peanut oil, soybean oil, sweet almond oil, tallow oil, and so on. The chemistry of saponification involves the hydrolysis of fats and oils by the action of sodium or potassium hydroxide in calculated or measured amounts. The reaction is generally exothermic thereby giving out some amount of heat in the process of product formation. In other words, saponification is the alkaline hydrolysis of the fatty acid esters.

1. The balanced Saponification equation for trimyristin and KOH is as follows:

$C_{45}H_{86}O_6$ + 3KOH -----> $C_3H_5(OH)_3$ + $3K^+$-$C_{14}H_{27}O_2$

trimyristin potassium hydroxide glycerol potassium soap

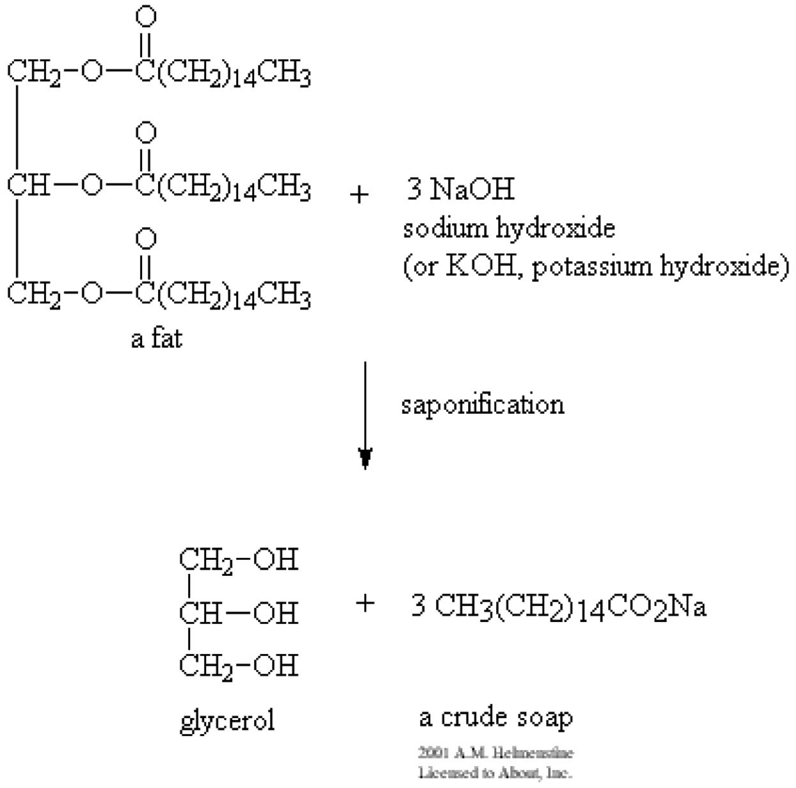

Figure 2: Saponification equations for producing soap and glycerol

Animation is the rapid display of a sequence of images of a two-dimensional (2-D) or three-dimensional (3-D) artwork or model positions in order to create an illusion of movement (see http://en.wikipedia.org/wiki/Animation). One of the chosen methods of instruction for the current research was a stimulated motion picture known as animation showing the actions and steps involved in the process of saponification. This was chosen with a view to bringing some degree of practical reality to the process and the associated chemical reactions to the learners outside the classroom and the laboratory. Mayer and Moreno (2002) opine that animation entails three main features, namely: (a) pictorial representation; (b) apparent movement; and (c) animation as a more or less artificial creation of events, objects, places and actions.

THEORETICAL FRAMEWORK

A review of the Cognitive Theory of Multimedia Learning shows that it is based on the following three possibilities or assumptions: (a) a limited capacity assumption that tends to show that only a few pieces of information can be actively processed at any one time in each channel (Mayer and Moreno 2002, 91; Sweller 1999, 47); (b) an active processing assumption that says meaningful learning occurs when the learner engages in cognitive processes such as selecting relevant material, organising it into a coherent representation, and integrating it with prior knowledge (Mayer and Moreno 2002, 91); and (c) a dual-channel assumption that portrays humans to have separate channels for visual/pictorial representations and auditory/verbal representations (Braddeley 1997, 167; Mayer and Moreno 2002, 95). Mayer and Moreno (2002) conclude that animation enters the learner via his/her eyes, so that he/she selects some images for further processing in the virtual channel; organises the images into a cause-and-effect chain; and then integrates them with the verbal material and existing knowledge. From the above discourse, animation appears to have some advantages that would enable learners to learn more, and to perform well either as individuals or in groups in such conditions that suit them best in time and space. It was upon this background that the researchers chose animation as one of the two multimedia approaches for this study with the other being Skype.

A cluster of seven principles for the effective use of multimedia including animation was put together as the result of Mayer and Moreno's research efforts to examine the conditions under which animation promotes learners' understanding in California. The principles are the: multimedia principle, spatial contiguity principle, temporal contiguity principle, coherence principle, modality principle, redundancy principle and personalization principle (Mayer and Moreno 2002, 93–96). The multimedia principle has a theoretical rationale that students are better able to build mental connections between corresponding words and animation when presented together than when words are presented alone in the form of lecture or dictation. The spatial contiguity principle shows that students learn more when on-screen text is presented next to the portion of the animation that it describes than when they are far apart. The temporal contiguity principle explains that students are better able to make mental connections when corresponding words and animation are in working memory at the same time. The coherence principle, otherwise called the 'exclusion principle' by the present authors, shows that students learn more from animation when extraneous sounds are excluded than when they are included in the teaching learning situation. The importance of this is to create the opportunity for the student's full attention and concentration on what is to be learned rather than having a situation where he/she pays attention to irrelevancies thereby making him/her less attentive to the expected cognitive resource for knowledge acquisition.

Skype was used in the study to further teach saponification to learners outside the classroom and laboratories as an extension of the ODL approach. In May 2010, Skype introduced its group video calling service that lets five people have a videoconference. Being software based, calls from Skype subscribers originate from their computers, and all computer-to-computer calls between subscribers are free, including video calls. The advantage of using this new technology in teaching is that it shows a real-life situation in terms of environment and practice to both teacher and students. Furthermore, the students participate actively as if they were in the same classroom or laboratory environment with their peers and the teacher, because they can see and hear everyone participating in the lesson.

PROBLEM OF THE STUDY

There is a perennial problem of a shortage of prospective science, medical and engineering students after the matriculation level in South Africa. These are the students who would have gone to universities for further studies and on graduation become part of the much needed manpower in the scientific, medical and engineering sectors. This problem is usually fundamental, foundational and is the result of a number of factors including a lack of laboratory facilities and equipment in many schools and teachers' pedagogical deficiencies among others. Researchers have reported similar problems at the tertiary and university levels. In the light of this, the problem of the study was to use animation and Skype to teach a selected chemistry topic to some 200 level chemistry students outside the four walls of the university laboratories with a view to solving the problem of reaching more learners at a time and without compromising the expected skill and knowledge levels acquisition in the subject.

PURPOSE OF THE STUDY

The purpose of the study was to provide an approach for increasing the quantity and quality of science students by the effective use of animation and Skype to suppress the challenges of a lack of and/or ill-equipped laboratories with very reduced costs. The use of these technologies enables the students to appreciate the aesthetic values of science; to increase their interest in and aptitude for science; and to become more positively inclined to studying science and science-related subjects in the future.

HYPOTHESIS OF THE STUDY

The study was guided by one alternative hypothesis, H_A. It states that there is a significant difference in performance between a group of students taught saponification chemistry by using the usual full contact classroom approach and those taught using the ODL approach of animation and Skype ($\boldsymbol{\alpha} < .05$).

POPULATION AND SAMPLE

All 200 level chemistry students at two universities formed the population of the study. To avoid crossing-over of information from one university to the other, the researchers kept the identities of the universities concealed from the participating students. A random sampling technique was used to select 15 willing participants in each of the control and experimental groups from among 200 level chemistry students at two universities. The samples were purposive and the members were of mixed achievement levels. The closer of the two universities was chosen for the full contact classroom control group and the other for the experimental group (using animation and Skype).

METHODOLOGY

The study involved the randomised control trial (RCT) design. The design is a trial because it allows subjects to be assigned randomly to one of two groups: Group 1 (the experimental group) receiving the intervention and Group 2 (the comparison or control group) receiving an alternative (conventional) treatment as is shown diagrammatically in Figure 3. The two groups are then followed up to see if there are any differences between the outcomes. The results and subsequent analysis of the trial are used to assess the effectiveness of the intervention. This is to determine the extent to which the treatment activities have done more good than harm. According to Kendall (2003, 164), RCT is the most stringent way of determining whether a cause-effect relation exists between the intervention and the outcome.

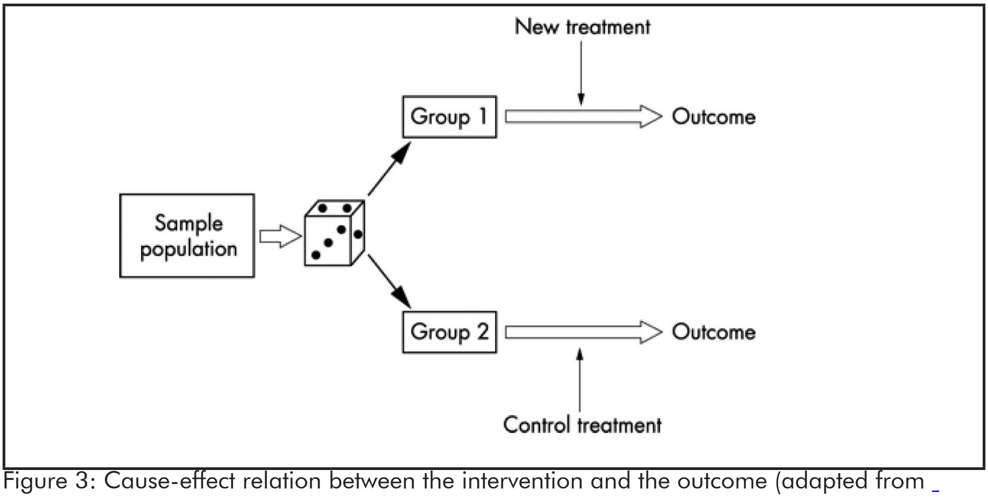

Figure 3: Cause-effect relation between the intervention and the outcome (adapted from Kendall 2003, 164)

In the current study, Group 1 was the experimental group where a new treatment in the form of teaching saponification chemistry by using animation and Skype was used on chemistry students outside the laboratories. The study involved the theoretical presentation of the concept of saponification and its entire chemistry and product in the first phase, followed by the practical activities in the second phase for both groups. The control group was taught by a volunteer research/lecturer assistant under a full contact classroom situation in Pretoria. The final and third phase of the study was the administration of a post-intervention test on the students with the researchers determining the outcome from the students' scores.

It was observed that saponification chemistry is part of the curriculum for second year or 200 level chemistry students for their first degree programmes at the two universities that participated in the study. This gave some level of a common foundational assumption irrespective of the fact that the samples were randomly composed of mixed achievers. For the purpose of the study, the common curriculum content on saponification as shown in Table 1 was applied.

Table 1: Research topic – saponification (Extract from Chemistry Syllabus, amended October 2002 and edited 8 July 2009, New South Wales Board of Studies)

Syllabus reference (October 2002 version)		
5. Saponification is an important organic industrial process	Students learn to: describe saponification as the conversion in basic solution of fats and oils to glycerol and salts of fatty acids describe the conditions under which saponification can be performed in the school laboratory and compare these with industrial preparation of soap account for the cleaning action of soap by describing its structure explain that soap, water and oil together form an emulsion with the soap acting as an emulsifier distinguish between soaps and synthetic detergents in terms of: the structure of the molecule chemical composition effect in hard water distinguish between anionic, cationic and non-ionic synthetic detergents in terms of: chemical composition uses	Students: perform a first-hand investigation to carry out saponification and test the product gather, process and present information from secondary sources to identify a range of fats and oils used for soap-making perform a first-hand investigation to gather information and describe the properties of a named emulsion and relate these properties to its uses perform a first-hand investigation to demonstrate the effect of soap as an emulsifier solve problems and use available evidence to discuss, using examples, the environmental impacts of the use of soaps and detergents

Table 1 shows the topic syllabus for the study and it was extracted from the amended chemistry syllabus of the New South Wales Board of Studies (2002). The syllabus considers the meaning and chemistry of saponification and its industrial applications for the production of soap and synthetic detergents. The choice of this topic was based on its dual abilities to provide cognitive development gains and practical skills that could make the students productive in the workplace after graduation.

ACTIVITIES OF THE STUDY

The preliminary activity of the study involved using the sampling process to identify students willing to take part in the project and to make arrangements for the provision of computer and internet facilities for those among the experimental group members who did not have such facilities. This was done by determining when they would be available to make use of a Cyber Café close to them as arranged by the research assistant in Addis Ababa. Figures 1 to 6 show the study participants at different stages of the teaching and learning programme using animation and Skype.

The researchers identified ten steps of animation activities from the theoretical meaning of saponification through the chemical reactions to actual soap production. The participants in the experimental group were requested to go to http://www.youtube.com/watch?v=0Zf11C-uTkQ&NR=1 (Faddy 2011) for animated saponification experiments. The students were pre-informed to make observations and take necessary records at every stage of the animation process. The steps are as follows:

1. Identification of needed chemicals and material components for a saponification reaction. These are the long chain fatty acids from either plants or animals and either sodium hydroxide or potassium hydroxide as the major reacting chemicals; additives such as essential oil blend, colorant and fragrance of choice. The needed material components include: a plastic container for the base (sodium hydroxide, NaOH or potassium hydroxide, KOH), a heat safe container (not made of glass), a top-loading measuring scale, a thermometer, a wooden spatula and a stainless steel container.
2. Weigh out some amounts (say 100 g) of sodium hydroxide in the plastic container.
3. Weigh out 283 g of distilled water in the heat safe container (able to withstand the heat of the reaction when the measured sodium hydroxide is dissolved the water). It is advised not to use impure water to avoid possible side reactions which could render the products of the saponification reaction unsafe for use.
4. Dissolve the measured sodium hydroxide in the 283 g of water by stirring with the wooden spatula. This is usually done carefully as much heat and fumes are given out in the process.
5. Place the thermometer into the solution to monitor the cooling to about 37.8 ^{o}C.
6. Prepare the chosen glyceride or oil for the saponification reaction in the stainless steel container.
7. Prepare the essential oil blend.
8. Slowly pour the cooled sodium hydroxide solution into the glyceride (fatty acid) in step 6 above stirring the mixture steadily with the wooden spatula until an

even colour and texture is achieved. At this point, saponification has occurred.

9. Stir the mixture slowly and gradually increase the speed as the texture thickens.
10. Pour in the essential oil blend and continue stirring until a perfect mixture is achieved. The chosen fragrance can also be added at this stage to enhance the beauty of the soap product.

LESSON EVALUATION

- The participants in the teaching programme were given some evaluation questions (oral and observatory) based on the topic using Skype.
- The participants were post-tested applying the questions in Appendix A: Saponification post-test questions (SPTQ) and the scripts were marked by the main author according to the agreed rubric for the test.
- Participants' responses showed their high appreciation and comprehension of the topic as a result of the teaching approaches used.

DATA ANALYSIS AND RESULTS

The post-test raw scores of the 15 research participants in each of the two groups are shown in Table 2.

Table 2: Post-test raw scores of the research participants

	Scores of students taught using the usual contact classroom approach	Scores of students taught using animation and Skype (Experimental)
	54	60
	66	66
	68	63
	51	60
	78	70
	52	72
	68	68
	62	66
	75	60
	77	50
	65	60
	60	78
	56	68
	50	79
	50	62

A close study of the scores shows that no student failed the post-test in the two groups considering 50 per cent as a pass mark and none of them scored up to 80 per cent and above. The implication of this observation is that the students in the two groups performed within a comparatively close range irrespective of whether they were taught in the usual contact classroom setting or by using animation and Skype. It further shows that science can be taught effectively outside the classroom and laboratory setting in line with the ODL approach as long as the recipient students are physically and mentally prepared and disciplined to achieve their set goals of wanting to do well.

The graphical representation in Figure 1 shows the class distribution of the raw scores of the students who took part in the post-test.

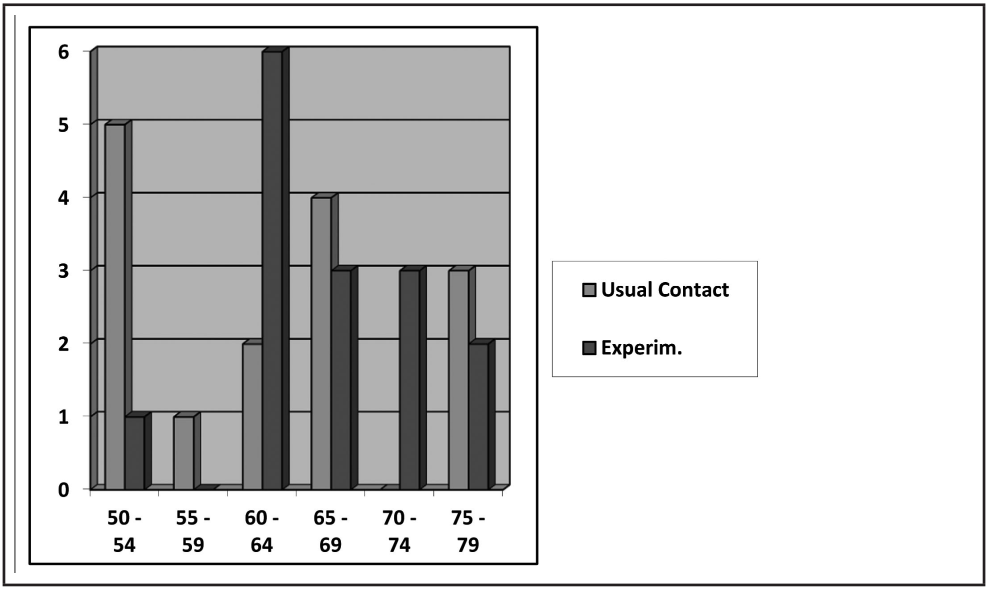

Figure 4: Graphical representation of students' post-test scores

Although the scores show a zero failure rate in the two groups, it was observed that of the six students who scored 50–54 per cent, five (83.3%) were taught by the usual contact classroom approach and just one (16.7%) was taught using animation and Skype. One of the 15 students in the control group scored between 55 and 59 per cent while no student from the experimental group had a score in this range. Eight students scored 60–64% made up of two (25%) from the control group and six (75%) from the experimental group. Four (57%) of the seven students who scored 65–69 per cent were from the control group, while three (43%) were from the experimental group. Furthermore, it was observed that both students who scored 70–74 per cent were from the experimental group. Finally, five students scored between 75 and 79 per cent made up of three (60%) students from the control group and two (40%)

from the experimental group, while no students from either group scored up to 80 per cent and above. The observed scenario points to the fact that the difference in performance level of students taught saponification chemistry in the two groups was not significant in comparison to the stated hypothesis of the study. In other words, the effectiveness of the two approaches used in the study appear to be closely paired depending on the competency of the users.

Table 3 focuses on the mean scores and standard deviation values of Group 1 (those taught using the usual contact classroom approach) and Group 2 (those taught using animation and Skype).

Table 3: Mean scores and standard deviation (SD) comparison for the control and experimental groups

Group	Student no. (N)	Mean Score (X)	Standard Deviation (SD)
Usual contact	15	62.13	9.86
Experimental	15	65.47	7.53

The results show a close set of mean scores of 62.13 for the students in the control group and 65.47 for those in the experimental group. However, a slight differential value of 3.34 in favour of the experimental group is noticeable with a lower standard deviation of 7.53 than that of the control group. This appears to have helped in a fairer score distribution among the experimental group students than those of the control group. It is also important to note that the seemingly lower standard deviation value of the experimental group tends to show that the approach is relatively more effective than the usual contact classroom approach for reasons that could be further researched.

Table 4: T-test result for the stated hypothesis, HA

Group	Student no. (N)	Mean Score (X)	Standard Deviation (SD)	**Standard Error**	**Critical *t*-value**	**Critical *t*-value**	***p*-value**
Usual contact	15	62.13	9.86		1.7011	1.0409	0.3068
				3.202			
Experimental	15	65.47	7.53				

It shows a *p*-value of 0.3068 by which the researchers failed to accept the stated alternative hypothesis that there is a significant difference in performance between a group of students taught saponification chemistry using the full contact classroom method and those taught using the ODL approach using animation and Skype. In the same vein, at a degree of freedom (df) of 28 the calculated *t*-value is 1.0409 and is slightly less than the critical *t*-value. Conventionally, this difference is considered not to be statistically significant. In other words, the two groups of students taught saponification chemistry appeared to show a similar performance level irrespective of the approach used. This disagrees with the general belief that chemistry and science in general can only be effectively taught within the classroom and laboratory confinements. With the cost of science equipment and facilities vis-à-vis the general unavailability of well-equipped science and chemistry laboratories in schools, the use of the ODL approach using animation and Skype would likely have some added advantages, such as helping to overcome the problems of cost and distance. This would provide the opportunity for many willing potential scientists and chemists to fulfil their dreams for the future.

DISCUSSION OF RESULTS

The study practically investigated the teaching of saponification reactions in organic chemistry to undergraduates using special ODL strategies outside the classroom and organised laboratories. The results of the study show that the ODL strategies used produced comparable performance levels among students taught the same chemistry contents using the usual contact classroom approach. Harrington (1999, 1–2), reporting on the result of Royse's study (1999), found no significant difference in student grades for those who took an in-person course and those who took a web-based course which is one of the many ODL strategies of teaching. This report agrees with the finding of the current study and is further supported by the finding of Hantula (1998 in Harrington 1999, 2; and in Piotrowski and Vodanovich 2012, 51).

They explained that students can learn course material as measured by course grades, as well from web-based instruction as they can from in-person lecture-based instruction.

The results of the study go further to show from the quality of students' performance in the post-test that more students in the experimental group had higher scores than those in the usual contact class even though no students failed in the two groups. The ODL approach used may have meant a more learner-centred approach, allowing greater flexibility and choice of content as well as a more personal organisation of the learning programme (Khvilon and Patru 2002, 20). The approach means more freedom of access to a wider range of opportunities for learning and qualification at the higher education level. It is a much cheaper alternative to doing courses and programmes through the conventional ways. Khvilon and Patru (2002, 20) note that the many advantages of ODL for students and employers are very important features from the perspective of government and policy makers. The approach increases access to learning and training, updating, retraining and personal enrichment. It is cost effective and enhances the quality of students' performance in virtually all subjects and disciplines including chemistry. Furthermore, the approach has no age barrier for learners and it extends geographical access to education for a large number of persons. ODL offers the possibility of organising learning and professional development in the workplace itself. The results of the study offer direct support for the statement that ODL provides speedy and efficient training for target groups (Khvilon and Patru 2002) and hence the students in the experimental group had more quality scores than those in the control group as shown in Table 2 and Figure 2.

CONCLUSION

The study has shown a strong possibility for the quality teaching of sciences to every willing learner (irrespective of distance, race and gender) at a lower cost than in the conventional institutions. The coherence principle, otherwise called the 'exclusion principle' by the present authors, shows that the learners learn more from animation when extraneous sounds are excluded than when they are included in the teaching learning situation. The use of animation and Skype supported the development of some measure of science process skills necessary for future development in science and the industrial sector. The study therefore showed that sciences, such as life science, physical science and other related disciplines, can be effectively taught and learnt through the ODL approach. Thus, the ODL approach to the teaching and learning of science is recommended.

REFERENCES

Braddeley, A. 1997. *Human memory.* Boston, MA: Allyn and Bacon.

Commonwealth of Learning and Asian Development Bank. 1999. *The ODL trainers' toolkit. Trainers' kit 003. Planning and management of open and distance learning*. Vancouver and Manila: Commonwealth of Learning and Asian Development Bank.

Faddy, M. J. 2011. Soap experiment (Saponification). Available at: http://www.youtube.com/watch?v=0Zf11C-uTkQ&NR=1 (accessed 30 April 2011) and http://en.wikipedia.org/wiki/Animations (accessed 2 April 2011).

Fafunwa, A. B. 1974. *History of education in Nigeria*. London: Allen & Urwin.

Harrington, D. 1999. Teaching statistics: A comparison of traditional classroom and programmed instruction/distance learning approaches. *Journal of Social Work Education* 35: 1–2.

Hulsmann, T. 1997. *Literature review on cost effectiveness in ODL systems: Working document*. Cambridge: International Research Foundation for Open Learning.

Kendall, M. J. 2003. Designing a research project: Randomised controlled trials and their principles. *Emergency Medicine Journal* 20(2): 164–168.

Khvilon, E. and M. Patru. 2002. *Open and distance learning: Trends, policy and strategy considerations*. Paris: UNESCO, Division of Higher Education.

Mayer, R. E. and R. Moreno. 2002. Animation as an aid to multimedia learning. *Educational Psychology Review* 14(1): 87–99.

New South Wales Board of Studies. 2002. Chemistry curriculum. Available at: http://www.boardofstudies.nsw.edu.au/hsc_exams/hsc2009exams/index5.html (accessed 7 March 2012).

Ochonogor, C. E. 1989. Facilities for teaching chemistry in Bendel state schools. BSc (Honours) project, University of Lagos.

Ojo, O. D., R. Ogidan and F. K. Olakulehin. Cost effectiveness of open and distance learning in Nigeria: Responses from focus group discussions. Available at: http://www.westga.edu/-distance/ojdla/summer92/david92htm (accessed 22 September 2009).

Piotrowski, C. and S. J. Vodanovich. 2000. Are the reported barriers to internet-based instruction warranted? A synthesis of recent research. *Education* 121(1): 48–53.

Sweller, J. 1999. Instructional design in technical areas, *ACER*. Available at: http://www.scribd.com/bojan2273/d/76775342-Instructional-Design (accessed 10 February 2012).

Thalmann, D. 2011. Using virtual reality techniques in the animation process. Switzerland, Swiss Federal Institute of Technology. Available at: http://wenku.baidu.com/view/4b51412f7375a417866f8f6f.html (accessed 10 February 2012).

Appendix A: Saponification post-test questions (SPTQ)

1. Describe saponification as the conversion in basic solution of fats and oils to produce glycerol and salts of fatty acids. [15 marks]
2. Describe the conditions under which saponification can be performed and compare these with industrial preparation of soap. [20 marks]
3. Explain that soap, water and oil together form an emulsion with the soap acting as an emulsifier. [20 marks]

- Distinguish between soaps and synthetic detergents in terms of:
- the structure of the molecule;
- chemical composition;

4. effect in hard water. [20 marks]
5. Solve problems and use available evidence to discuss, using examples, the environmental impacts of the use of soaps and detergents. [25 marks]

Points you should mention in your discussion include:

- Biodegradability (soap most biodegradable, anionic detergents usually fairly biodegradable and can precipitate out with cations, non-ionic detergents are low-sudsing and usually biodegrade, cationic detergents can kill some of the microbes that biodegrade the detergent so are the least biodegradable).
- Presence of phosphates.
- Entry into and effects on waterways including eutrophication.
- Measures to overcome problems.

ACKNOWLEDGEMENT

We wish to acknowledge the cooperative attitudes of Mr Chinaka Taurayi Willard for helping to teach the control group in South Africa and Mr Tesfaye Demissie Hailegebreal who gave his time to identify and arrange for the students in the experimental group of the study in Ethiopia. Our profound gratitude also goes to all the students who volunteered to take part in the study.