M.J. George,
S. Afr. J. Chem., 2014, **67**, 113–117,
<http://journals.sabinet.co.za/sajchem/>.

Exploration of the Potential of using a Virtual Laboratory for Chemistry Teaching at Secondary School Level in Lesotho

Mosotho J. George* and 'Mamontsi Kolobe

National University of Lesotho, P.O. Roma 180, Lesotho, Southern Africa.

Received 27 June 2014, revised 8 August 2014, accepted 2 September 2014.

ABSTRACT

With the ever-increasing economic challenges facing education in Lesotho and indeed the world at large, there is a need for innovative solutions to support academic programmes without compromising quality. The use of computer simulations and video demonstrations is increasingly finding use globally in order to respond to economic challenges and purportedly to improve understanding of abstract phenomena. This manuscript presents the views of the chemistry teachers and students registered at the National University of Lesotho (NUL) towards the development of a Virtual Laboratory (VL) where the experiments in the secondary school chemistry syllabus, will be video-recorded and distributed to schools. The results demonstrated a need for VL since only 4 % of the respondents indicated having performed more than 10 experiments with reasons ranging from poorly equipped laboratories (66 %) to no laboratories (6 %) for fewer to no experiments having been performed. This venture is generally accepted (96 % of 166 respondents) with only a minority stating it can never replace physical laboratory. Distribution of the VL would require innovative means since internet accessibility seems a challenge for most schools with accessibility of only 35 %.

KEYWORDS

Lesotho, secondary school chemistry, experiments, poorly equipped laboratories, virtual laboratory.

1. Introduction

Education is one of the most expensive investments any country can make in its human resources development. This is more so in developing countries characterized by low gross domestic product where most of the citizenry does not have sufficient resources to pay for their children's fees. Lesotho is classified as a developing country and hence suffers the same fate as other developing countries.[1] However, the Government of Lesotho is committed to ensuring that Basotho can access education through the provision of the basic and functional literacy. There are still a number of challenges such as taking care of animals; acting as heads of families; having unemployed parents and being victims of poverty that to some extent still pose a threat to access to formal education.[2] This is despite the introduction of universal access to primary education, advocated by the World Bank and United Nations over a decade ago in Lesotho.[3]

Financing of secondary education is still a challenge given that ownership of schools in Lesotho is either public or private. The public schools category includes government-, church- and community-owned schools.[4] This category receives some form of support from the government mainly for salaries of the teachers, although the salaries are low and often payment is delayed.[5] In the latter scenario, private individuals or a consortium of people privately own a school and the government does not contribute anything to such schools except the registration and certification/accreditation of such schools to meet the minimum requirements of the secondary education. The 2010 statistics reportedly revealed about 92 % of over 300 public secondary schools are owned by churches, demonstrating the integration of government, the churches and the community in education in Lesotho.[4]

Teaching of science and technology-based subjects such as Biology, Chemistry, Agriculture and Physics, requires a lot of investment in resources such as laboratories, chemicals and other facilities, in addition to the common teaching aids such as blackboard and chalk requisite of other subjects. This further puts strain on the schools that offer these subjects: there are many schools that offer science subjects with limited resources such as lack of laboratory space, laboratory equipment, consumable supplies and sometimes even a shortage of qualified science teachers.[6] A quick survey of the students that register for the First Year in the Faculty of Science and Technology at the National University of Lesotho has demonstrated that some students have either not performed any experiments by themselves or seen demonstrations by their teachers, while some reportedly have not been inside a laboratory. This situation generates some level of anxiety and poor confidence in the students, hence generally leading to poor performance in the early stages of university study.[7]

In situations like these, Chemistry suffers the most since most of the chemistry experiments require use of chemicals and at the end such chemicals are discarded and are not recyclable. This has caused a number of schools either to evade teaching chemistry or to teach the theory only without any experiments. This deprives the students the benefits gained from performing experiments such as arousing interest in the subject,[8] and connecting the sometimes abstract theory to the real world. This leads sometimes to students losing interest and eventually leaving the sciences.[9]

In response to some of the challenges relating to performing physical experiments there has been a shift towards the use of a virtual laboratory in the form of video demonstrations, animations and other internet-based resources, and these have been adopted and are quite common in the Developed World.[10] These simulations reduce the risks associated with the often hazardous materials such as acid fumes and explosive reactions and reduce the time taken for preparations and for performing the actual

* To whom correspondence should be addressed.
E-mail: jm.george@nul.ls / maluti2005@gmail.com

experiments, whether demonstrations or by the students.[11] Incorporation of video streams during a lesson creates a potential for enhancing a symbiotic relationship between the two, since part of a video stream can be previewed during a lecture to stimulate the students' interest as well as relieve the teacher of the need for repeated demonstration.[12]

Video demonstrations and animations are also believed to improve students' correlation of macroscopic, sub-microscopic and symbolic levels of scientific presentation.[13] There are a number of web-based resources for teaching and experimental demonstrations for sciences such as Virtlab, The Chemistry Collective, Royal Society of Chemistry Demonstration Videos, to mention but a few.[10] However, these resources still need some investment in terms of procuring access licenses, dealing with software glitches and not mere internet access.[14] This may pose a serious limitation for schools in Lesotho.

This manuscript is aimed at exploring the perception and reception of the idea of the development of a Virtual Laboratory (VL) for secondary school chemistry experiments. Most of the VLs accessed online are designed for distance university learners not secondary school learners. The videos will not only show images of the experiments, but also give oral recitation of the procedure and describes the results as the experiment is being run. This mode is believed to be able to reduce the expenses of carrying out all experiments physically, especially those where the observations can be made through sight and hearing and despite leaving out the other senses such as smelling, tasting and touching, which in any case are not recommended. The study was based on a very limited sample of teachers, student teachers and some first-year students at the National University of Lesotho totalling 166, as a preliminary study to support a proposal for funding towards this exercise.

2. Methodology

The research was designed to give evidence of the need for the proposed VL by the Department of Chemistry and Chemical Technology of the National University of Lesotho. A sample of 166 respondents, comprising final year student-teachers who were in their teaching practice/internship (20), their mentor teachers (12) during the three-month internship and some first year students (134) in the Faculty of Science and Technology of The National University of Lesotho picked randomly from practical sessions. The responses were mostly through the questionnaire, with only a few cases being engaged in verbal interviews to establish understanding of the questions.

Questions were primarily designed to:

- establish the status quo in the schools where the respondents worked or underwent their secondary education;
- establish the perceived importance of experiments in teaching of chemistry
- identify if a sufficient number of experiments were performed
- identify reasons why insufficient experiments were performed
- identify the areas of chemistry covered through the type of experiments performed
- establish appreciation of the Virtual Laboratory concept
- assess the internet accessibility so as to establish the appreciation of web-based resources and to also gauge the suitability for distribution of the VL, once developed.

Secondary aspects of the questionnaire were to establish the district where the respondents underwent their secondary schooling. The respondents were not classified as teachers or students but were mixed together in the analysis.

3. Results and Discussion

3.1 Teaching of Chemistry at Secondary School Level

To establish how commonly the science subjects were offered in schools, the respondents were asked if their schools taught chemistry. Interestingly only one respondent, who was a science teacher in one of the schools that was sampled, indicated not having done chemistry at school more than 10 years ago. This was possible since to be admitted into a university for a science related degree, one was required to have done any two of the secondary school sciences (Biology, Chemistry and Physics). This was not a surprise since the target group was already pursuing the science-based programmes.

3.2. Role of Experiments

Experiments are generally perceived to aid teaching and to improve understanding of the pupils of sometimes abstract phenomena. This was indeed the most cited benefit as in Fig. 1. Teachers and students were asked what role they think experiments play. To avoid overlaps, each respondent was asked to mention the most important to them.

From Fig. 1 it can be seen that 59 % of the respondents stated that experiments improve chemistry understanding. Some teachers mentioned that experiments help them prepare better for their lessons. However, there seemed some confusion between preparation and teaching. Some teachers mentioned

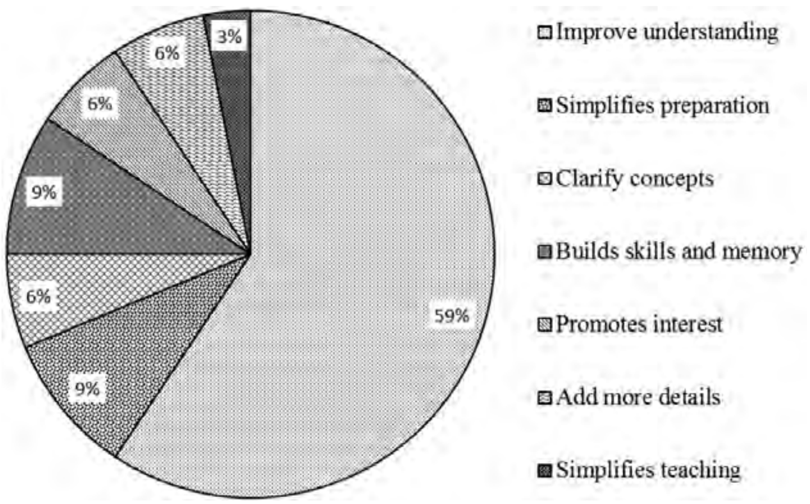

Figure 1 The role of experiments in teaching and learning of chemistry in schools.

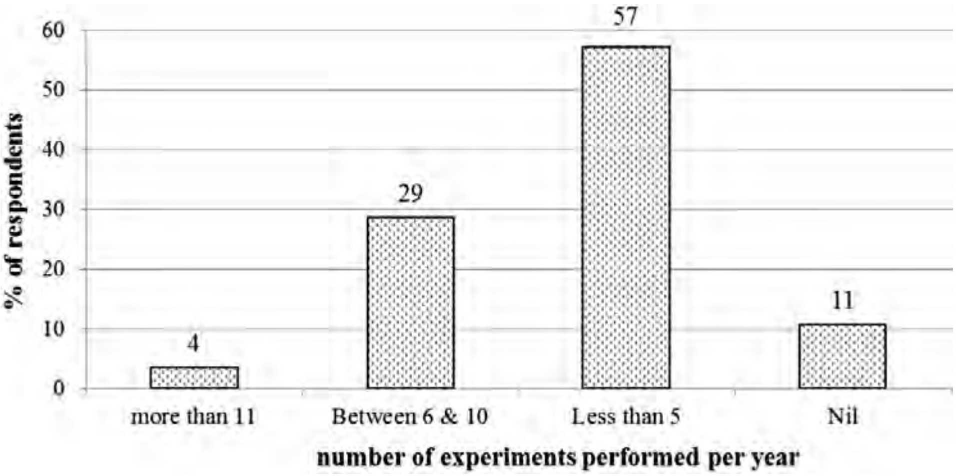

Figure 2 The number of experiments performed per year at a secondary school.

that sometimes they would use experiments before teaching some topics and from the experimental sessions they deduce which areas need more attention in class as such experiments seemed to simplify preparation. Others explained this same principle to be assisting in teaching not preparation.

3.3. Number of Experiments Performed per Year at Secondary School Level

Figure 2 shows the percentage of the respondents and the number of experiments carried out per year in the schools that have laboratories and those which did not. In some of those schools that did not have laboratories, some teachers indicated they used classrooms for carrying out demonstration experiments, though not necessarily for chemistry experiments but for all science subjects.

It is clear from Fig. 2 that most schools did not perform a satisfactory number of experiments for various reasons that will be presented in Fig. 3. Only 4 % of the respondents indicated they had done more than 11 experiments (only two respondents did more than 15, others could not remember the number but they were less than). Interestingly there was no material difference between the rural and urban schools. The experiments that were most popular included the reactivity of group 1 metals (specifically using sodium metal), reaction of metals with acids and production of hydrogen gas and its test, precipitation, production and test for carbon dioxide using $Ba(OH)_2$.

3.4. Reasons why Experiments not Done

The purpose of this section was to explore some of the reasons why the experiments were not performed. The assumption was the absence of laboratories as well as the consumables. Of the 166 respondents only three (one of which was a teacher), stated that they never asked for the reasons why the experiments were not done, since they had not seen anyone doing them since joining their respective schools. Figure 3 shows the responses given and their distribution over the participating population (161) disregarding the three who did not have reasons.

Looking at Fig. 3, only 6 % of the respondents cited that their schools did not have laboratories. Further inquiry into this revealed that these respondents came from the recently built government schools some of which were still in the process of constructing laboratories. Then the big question is, if about 95 % of respondents came from schools that have laboratories why don't they do the chemistry experiments? The main reason cited by almost 70 % (66 % and 3 %) of the sampled population was lack of consumables and broken or lack of basic equipment such as beakers, measuring cylinders, weighing balances, etc. The mention of failing experiments (6 %) could also be attributed to the same issue of lack of consumables and sometimes expired or pre-used chemicals which compel the teachers to sometimes improvise. Where the improvised version fails, such teachers are frustrated and this may lead to loss of confidence and avoidance of further experiments.

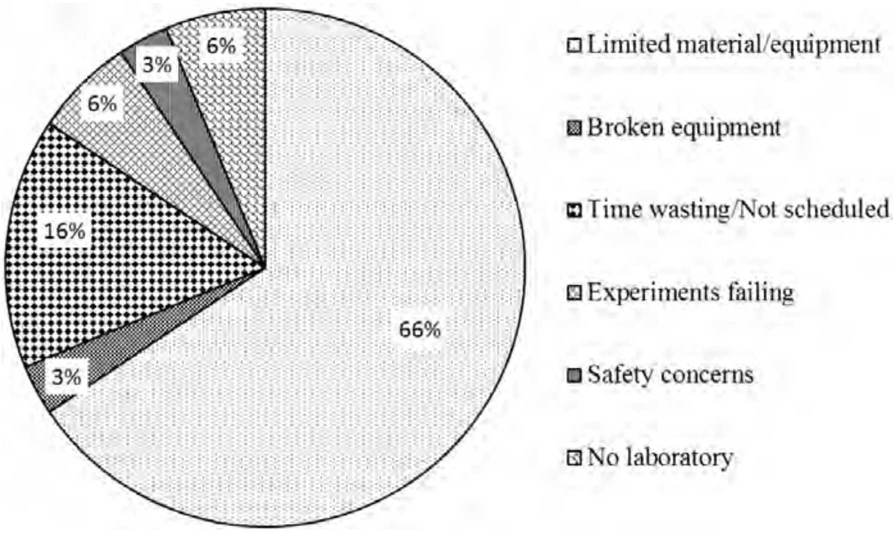

Figure 3 Reasons cited by teachers why fewer (or no) experiments were performed.

The other factor shared by 16 % of the population, and the most serious to the authors, is that experiments are not normally scheduled on the timetable, let alone the preparation time, leaving those teachers with enthusiasm to sometimes not attend other extracurricular activities such as sports, to use that time for improvisation and preparing for experiments. This situation apparently creates tensions between the teachers who participate in such activities and those that would rather use that time for preparation and actual carrying out of the experiments. The non-scheduling of the experiments in the timetable renders experiments an extra burden to the teachers (and students alike) since they carry the normal loads as other teachers in the arts subjects. This is a normal trend even at tertiary level; teachers and students in the sciences always carry the heaviest load in order to cater for the experiments, which are generally regarded as the same credit as lectures in the arts subjects.

Safety issues were cited by only 3 %, which were teachers. These teachers mentioned that this was mainly due to the large numbers of classes, and the usually playful character of the students. The lack of safety kits (first aid kits), fume-hoods, running water, fire extinguishers, etc., in some schools also exacerbated this scenario.

3.5. Use of Moving Pictures (Videos and Animations) in Teaching

Only 13 % of the respondents mentioned ever using videos in teaching/learning. There was generally poor appreciation of the existence of some useful web-based educational resources despite 35 % of the respondents' schools reportedly having internet access. It was stated that the internet was used mostly for communication, sending e-mails and rarely as a teaching aid. The respondents despite all having smart mobile phones that can access internet, stated they hardly ever used these gadgets for school work, whilst the internet was mostly used for entertainment. No respondent was aware of the existence of web-based demonstrations and animations for chemistry experiments.

3.6. Appreciation of the Proposed Virtual Laboratory Concept

Having established that generally respondents were not aware of electronic sources of animations and moving pictures, respondents were thereafter asked what their perceptions would be towards the use of a Virtual Laboratory for chemistry experiments. Unlike in the preceding sections where the respondents were restricted to one response, in this case they were asked to enlist any of the responses they could provide. The responses are as shown in Fig. 4.

The new issues raised by this question, in addition to those cited for the role of experiments (which are regarded as just confirming the general importance of experiments) included: lack of or shorter preparation for both teaching and experiment sessions (mentioned by 6 % and 9 % in Fig. 4), no failed experiments (9 %), reduced disturbances/chaos in the laboratory session (3 %), general passion of students to electronic media in general which some respondents termed 'addiction' (6 %). Some 3 % of the respondents stated that some students are 'visually intelligent'; hence the electronic media could be appealing to them and keep them interested and avoid losing concentration.

Amazingly, 3 % of respondents who were first-year students in the Faculty of Science and Technology, stated that they categorically did not support the proposed Virtual Laboratory. Their reasons were that physical experiments are the only form that can work, since beyond secondary education such students would have to perform authentic experiments. This is in agreement with Woodfield *et al.* who stressed that authentic physical experiments hone students with practical laboratory skills required to undertake real experimental tasks within a real laboratory.[15] However, these respondents seem generally to be somewhat ignorant of the prevailing circumstances or even the spirit with which this venture would be tried although their observations were noted. The limitation brought by the absence of real sensations like touching or smelling was also reported by Tatli and Ayas.[16] However, this should not be regarded as a limitation since the same students appreciated that they were being barred from sniffing or tasting chemicals for their own safety no matter how safe some chemicals may be.

In response to why they did not perform many experiments, most (69 %) stated lack of equipment/apparatus and consumables (Fig. 3). As such it came as a surprise that this percentage dropped to 28 % when the benefits of the VL concept were considered. Disregarding the response of enhancing understanding (19 %) (covered in Fig. 1) still leaves only about 35 % stating cost of equipment and chemicals as the main benefit. However, the respondents seemed not to appreciate other cost implications such as waste disposal, especially in the context of climate change and preservation of the environment. Waste

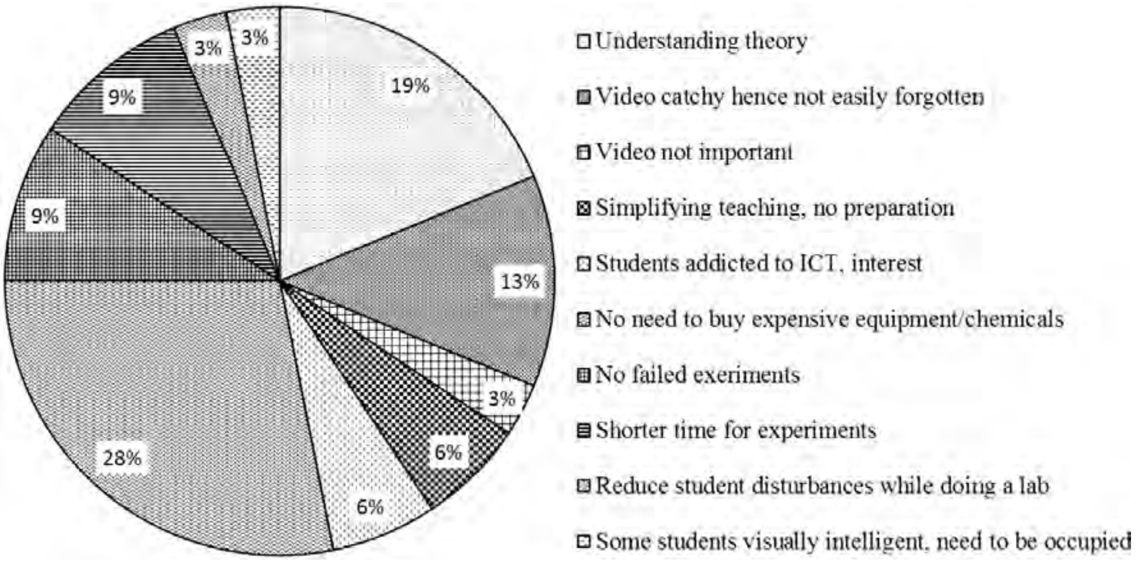

Figure 4 Some potential benefits of the virtual laboratory to both students and teachers.

disposal has become a thorny issue recently requiring commitment by all stakeholders; as such, schools are expected to play a leading role since some of them are hosted in very rural areas where there is generally poor appreciation of these aspects. This issue stresses the need to incorporate environmental issues across different curricula.

The safety concerns were not mentioned. These issues would be taken care of when using the VL since few experiments would be performed physically. The reason this was not stated could be attributable to the fact that safety was mentioned by very few teachers as a cause of little experimentation. The general disregard for safety could be due to the fact that most of the respondents, who are current and former students of NUL, could have acquired a less serious attitude towards safety. This calls for introspection on the NUL as an institution, lest it appears that staff that do not instil safety awareness in the students.

The issue of specific and relevant content as well as accent were raised by some people (including some of the respondents) during the post-analysis discussions and the review of the manuscripts by the peers and students. It appeared that students would relate better with faces they can recognize, rather than downloading some material generated elsewhere, which could be suitable for different curricula but not the specific local curriculum. It was reported that some students may also battle to understand different accents accompanying the existing web-based VLs. The specificity of the local VL to the local syllabus was stressed in support of the VL concept.

4. General Discussion and Conclusion

This manuscript has indeed confirmed some of the concerns of the authors, that most students that register for the first year in the University have performed few, if any, experiments in their secondary education. This thus means that such students require a lot more attention during the experimental sessions in the sophomore year. The myriad assortment of reasons why experiments were not performed also demonstrates the complexity of the prevailing circumstances. Of critical concern is the issue of the timetable; without timetabling of experiments teachers would have to carry out experiments outside the timetable in extra time. This is not acceptable if the country is to produce quality scientists. As Beach and Stone put it in 1988 'chemistry education without laboratory is like painting without colours and canvas or learning how to ride a bike by reading its operating manual'.[17] The general lack of equipped laboratories stresses the importance of the VL concept as proposed. The study has revealed that this concept can be adopted as an alternative to, but not a substitute of the physical laboratory experiments.

With the internet accessibility of less than 35 % in schools, the distribution of the proposed Virtual Laboratory product would also have to be innovative so that some nominal funds can be generated for support of the facility for future improvements and general support for continuity. There seems a need to advise schools about the importance of investing in internet facilities, even if not for students but rather for teachers. Cell-phone penetration in Lesotho is almost 90 % with the majority of areas being able to access signal. The challenge that is anticipated, however, is the absence of electricity in some rural places in Lesotho. However, solar and wind-generated power could also be put to use.

Acknowledgements

The authors would like to sincerely acknowledge the teachers, Year IV student-teachers and first year students of the National University of Lesotho that participated and allowed their views to be shared in this manuscript.

References

1 World Bank, World Development Indicators, retrieved on 31 May 2014 from http://data.worldbank.org/country/Lesotho
2 P. Lefoka, Commonwealth Education Partnerships, 2007, retrieved on 12 May 2014 from http://www.cedol.org/wp-content/uploads/2012/02/212-215-2007.pdf
3 M.N. Ntho, Review by AfriMAP and the Open Society Initiative for Southern Africa, 2013. Open Society Foundation, Johannesburg, South Africa.
4 C.M.L. Bitso, *TOJDE*, 2006, **7**(1), retrieved on 25 March 2014 from https://tojde.anadolu.edu.tr/tojde21/pdf/article_3.pdf
5 http://www.educationincrisis.net/country-profiles/africa/item/504-lesotho, accessed 12 May 2014.
6 T. Maqutu, *Afr. J. Res. SMT Educ.*, 2003, **7**, 97–107.
7 B. Dalgarno, A.G. Bishop, W. Adlong and D.R. Bedgood Jr., *Comput. Educ.*, 2009, **53**, 853–865
8 W.S. Harwood and M.M. McMahon, *J. Res. Sci. Teach.*, 1997, **34**(6), 617–631
9 M. Prince and R. Felder, *J. Coll. Sci. Teach.*, 2007, **36**(5), 14-20
10 R.D. Jansen-van Vuuren, M.S. Buchanan and R.H. McKenzie, *J. Chem. Educ.*, 2013, **90**, 1325-1332
11 L.H., Laroche, G. Wulfsberg and B. Young, *J. Chem. Educ.*, 2003, **80**(8), 962-966
12 K. Fill and R. Ottewill, *Innov. Educ. Teach. Int.*, 2006, **43**(4), 397-408
13 A. Velázquez-Marcano, V.M. Williamson, G. Ashkenazi, R. Tasker and K.C. Williamson, *J. Sci. Educ. Technol.*, 2004, **13**(3), 315-323
14 B. Dalgarno, A.G. Bishop and D.R. Bedgood Jr, *UniServe Science Improving Learning Outcomes Symposium Proceedings*, retrieved on 7 June 2014 from http://openjournals.library.usyd.edu.au/index.php/IISME/article/view/6527/7174
15 B.F. Woodfield, M.B. Andrus, T. Andersen, J. Miller, B. Simons, R. Stanger, G.L. Waddoups, M.S. Moore, R. Swan, R. Allen and G. Bodily, *J. Chem. Educ.*, 2005, **82**, 1728–1735.
16 Z. Tatli and A. Ayas, *Proc. – Social Behav. Sci.*, 2010, **9**, 938–942.
17 D.H. Beach and H.M. Stone, *J. Chem. Educ.*, 1988, **65**(7), 619–620.