A triggering strategy for improved pass rate in software-managed evaluations of Physics practicals for the Engineering Programmes at the University of Johannesburg

Leelakrishna Reddy, Padmanabhan Nair, Sam Ramaila and Jan Oelofse

Department of Applied Physics and Engineering Mathematics, University of Johannesburg, Doornfontein Campus, P.O. Box 17011, Doornfontein, 2028

E-mail: samr@uj.ac.za

Abstract. The non-traditional approach to the evaluation of Physics practicals through an innovative software embedded system, first of its kind in South Africa, allows students to execute and report the results of an experiment independently. This system evaluates the individual performance in an experiment in terms of accuracy, analysis of data and report of the results obtained. As part of the evaluation of the experimental report, the student's data is loaded into a software system and checked against the pre-loaded data for a particular experimental work station. Thus, students are unaware of the exact requirements for securing marks at each step and process of the report. To overcome this difficulty, the experimental group of students were given support through rigorous tutorials and consultations in contrast with the control group. Results reveal that the support system appears to have huge potential in terms of the improvement of student performance with regard to practical work. The observed improvement of student performance is viewed in a positive light as a potentially valuable outcome that can meaningfully inform pedagogic innovation in recognition of the fact that Physics practicals carry a full modular credit in the diploma programmes offered by the Engineering Faculty at the Doornfontein Campus of the University of Johannesburg.

Keywords: experimental skills, strategy, practicals, engagement, mentorship

1. Introduction

It has repeatedly been observed that the first-time entering students enrolled for Diploma programmes at the University of Johannesburg lack the basic experimental skills needed in Physics such as observations and manipulation of equipment as well as communication skills such as reporting of observations and results [1]. This skills deficiency is most prevalent in many students coming from under-resourced public schools in South Africa. These students come to tertiary institutions with an inherent fear for practical work. The Department of Applied Physics and Engineering Mathematics (APEM) of the University of Johannesburg responds innovatively to the critical challenges associated with lack of practical skills. The students doing Physics as a service module in the Engineering Faculty are introduced to an array of uniquely designed student friendly and interactive fundamental practicals in Physics.

Contrary to the traditional assessment approach to practical work, APEM developed a software embedded rubric marking system that is linked to a database of 350 practicals housed in 7 laboratories. This approach seeks to ensure that students perform meaningful practical work through the provision of opportunities for meaningful interaction with the materials, data collection and analysis as well as making sense of the natural world [2]. Such an innovative assessment marking system has many parameters. This article reflects on a triggering strategy taking the form of support and controlled mentorship through engagement. It is envisaged that this strategy would serve to demystify the fear associated with practical work and enhance laboratory skills.

2. The purpose of practical work in science

Various arguments have been advanced in an attempt to make sense of the aims of practical work in science, namely, cognitive arguments, affective arguments and skills arguments [3]. Cognitive arguments advocate that practical work can improve understanding of science and promote conceptual development through visualisation of laws and theories of science thereby providing opportunities for illustrating, verifying or affirming theory [3]. Affective arguments advocate that practical work provides motivation and excitement as well as the generation of interest and enthusiasm [3]. Skills arguments advocate that practical work promotes development of higher-level transferable skills such as observation, measurement, prediction and inference [3].

At another level, several counter arguments to all these claims for practical work have been advanced. These arguments are premised on the notions that doing science and understanding science theories are two different entities [4], and that there is evidence that many students are not very positive about doing experiments [5] as well as the existence of the evidence that the transferability of skills is limited [6]. Clearly, the discourse pertaining to the aims and purpose of practical work is a contested terrain in many ways. In fact, the plurality of espoused aims for practical work in science make the task of assessment increasingly difficult [7].

3. The place of practical work within the science curriculum

It has been argued that the centrality of the laboratory to the teaching of science has become like the addicts' relationship to their drug – an unquestioned dependency which needs to be re-examined and weakened if not broken altogether [8]. It has also been noted that despite a shift of emphasis towards learning outcomes, the evidence suggests that there is a chasm between what teachers identify as their outcomes before lessons and the outcomes that their students perceive [9]. A major hurdle that has been identified earlier is that despite the aim of curriculum reform at improving the quality of practical work, students spend too much time following 'recipes' and, consequently, practising lower level skills [10] leading to failure to perceive the conceptual and procedural understandings as intended goals for the laboratory activities [11].

4. The role of information technology in supporting teaching and learning in practical work

Significant technological innovations have offered new resources for teaching and learning, but insufficient attention has been directed to examine critically how these new technologies can enhance or confound experiences in the laboratory [11]. In fact, it has been claimed that rapid advances in technology offer a wide range of new opportunities for innovative science education [12] which include the use of sensors, simulations and the internet [13]. Vitals tools such as computer-based simulations may also help to reduce the noise associated with the laboratory bench and focus attention on important aspects of experimental planning and data interpretation [14]. In addition, computers and their peripherals can be used to aid long-term investigations, for example, in data-logging experiments [15] and can also be used in visualizing data as well as modelling scientific phenomena [16]. Given the potential of the role of information technology in supporting practical work, a software-embedded system to evaluate physics practicals was developed at the University of Johannesburg.

5. Methodology

Students enrolled for Electrical Engineering Diploma were participants in the implementation of the engaged triggering strategy mechanism because of their comparatively lower achievement levels in Grade 12 Physical Science. A total of 178 students were randomly divided among 4 staff members resulting in two groups per staff member. These groups of students were accordingly allocated labels A1, A2, B1, B2, C1, C2, D1 and D2 and each group performed a total of 17 practicals during the semester. The groups of students with labels D1 and D2 were regarded as the experimental group due to the specific implementation of the engaged monitoring strategy and the other groups with labels A1 to C2 were called the control groups.

Each student is required to purchase a Laboratory Manual and a Laboratory Result Book [17] as key instructional resources. The Laboratory Manual contains theories, methods and procedures while the Result Book provides templates for data collection, calculation of unknown parameters, plotting of graphs and submission of the final report. At the beginning of each practical session, students are briefed on the practicals to be performed before being afforded the opportunity to perform the practicals individually. A typical laboratory cubicle and excerpt from the Result Book are shown Figures 1 and 2 below. On completion of the experiment, students are afforded an opportunity to discuss related laws and theories coupled with a comprehensive explanation of the pitfalls and expectations of the excel rubric marking programme (ERMP).

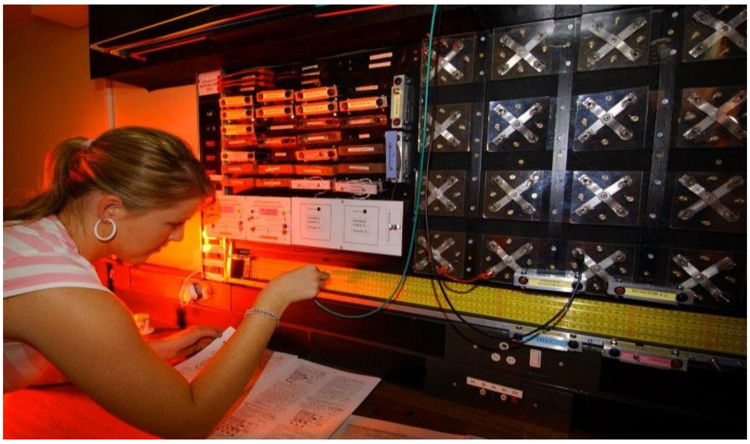

Figure 1: Laboratory cubicle

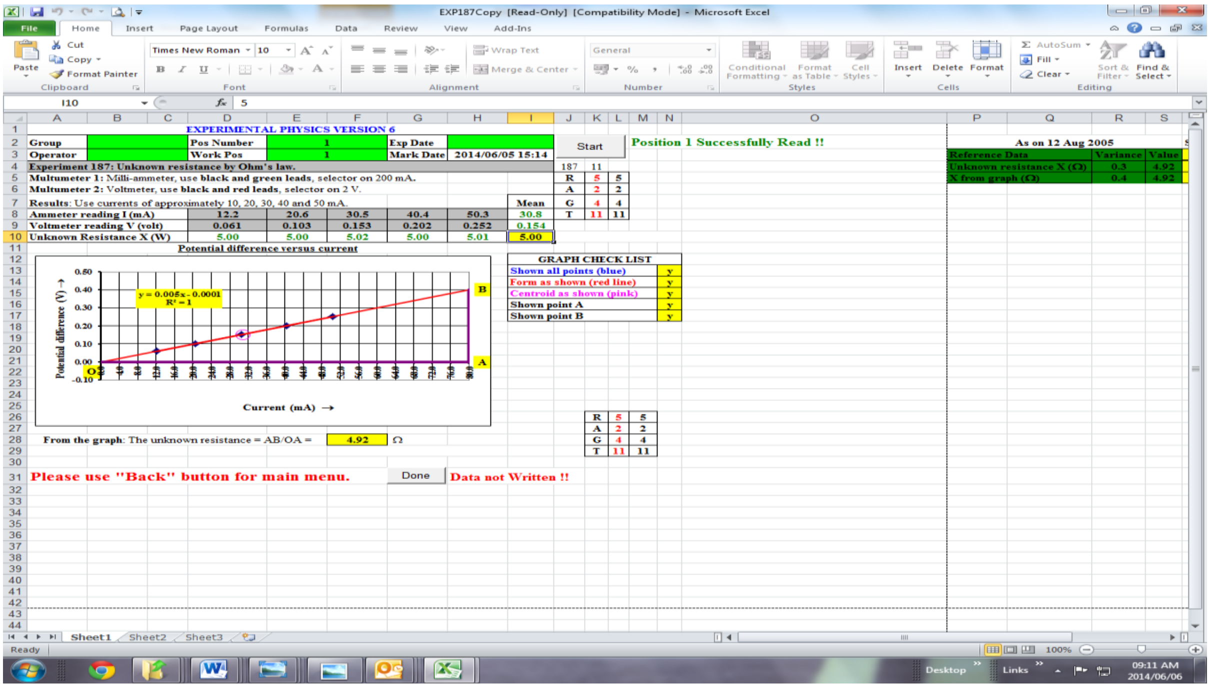

Figure 2: Excerpt from the Result Book

A set-up for a typical electricity experiment (EXPERIMENT 187) is depicted in Figure 3 below.

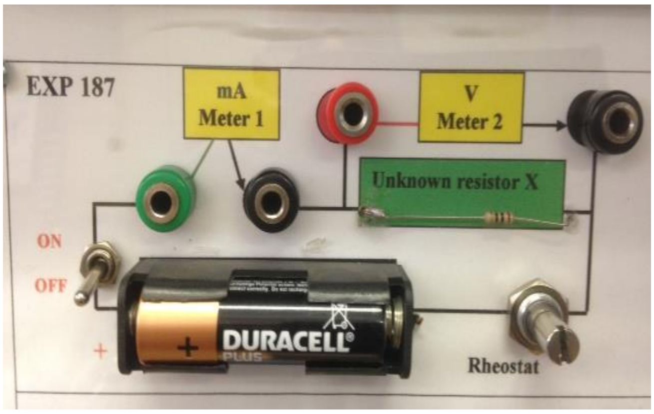

Figure 3: Illustration of Experiment 187

In addition, the students were given few days to perform necessary calculations and plot graphs as part of laboratory report before presenting it to the lecturer for critical scrutiny before final submission. This takes the form of a compulsory consultation. The rules are gradually relaxed as the students become familiar with the pitfalls associated with the software embedded assessment system. Suffice to indicate that students who fail to present their work for critical scrutiny incur penalties.

6. Discussion

Analysis of the marks of the six experiments numbered EXP 187-190 and 193-194 from the various groups A1 to D2 is shown in Table1 below.

Table 1: Mark analysis for the six experiments performed

	Group allocation						
Experiment number		187	188	189	190	193	194
Control group	A1	65%	84%	81%	40%	73%	33%
	A2	72%	85%	79%	61%	81%	74%
	B1	76%	83%	78%	51%	83%	54%
	B2	Did not do these experiments					
	C1	79%	85%	78%	67%	88%	59%
	C2	79%	85%	78%	67%	88%	59%
Average		**75%**	**85%**	**80%**	**57%**	**80%**	**58%**
Experimental group	D1	85%	88%	83%	66%	75%	72%
	D2	79%	85%	78%	67%	88%	59%
Average		**86%**	**94%**	**89%**	**76%**	**86%**	**74%**
Shift in % mark		+11%	+9%	+9%	+19%	+6%	+16%

The experimental group demonstrated improved performance as compared to the control group. Percentage shifts suggest benefits that accrue from the engaged strategic intervention programme. A comparison of the semester overall performance is shown in Table 2 below.

Table 2: Comparison of the semester overall performance

	Control group						Experimental group	
Groups	A1	A2	B1	B2	C1	C2	D1	D2
Overall percentage	66%	70%	68%	67%	65%	65%	76%	79%
							Average = D1 + D2 = 78%	
Shift in % marks	-12%	-8%	-10%	-11%	-13%	-13%		

The improved overall performance demonstrated by the experimental group points to the potential efficacy of the intervention. It has to be accentuated that the majority of students in South Africa have limited practical exposure and this is commensurate with South Africa's global ranking in terms of the quality of mathematics and science education as well as the quality of the education system [18].

Appropriate and concrete steps geared towards the development and improvement of instruction with the potential to enhance pedagogic innovation within a broader South African context are required in the light of the key findings in this inquiry. The prevailing articulation gap which appears to be a result of the conflation of various factors ought to be adequately addressed in order to significantly improve the overall quality of the education system within the South African context and the development of innovative strategies that can serve to enhance practical skills is no exception.

7. Conclusion

The heterogeneous sample of 178 students comprising experimental and control groups is a reasonably good representative sample of students performing practicals in the Physics laboratories as the highest number of students come from the Engineering Faculty. The engaged mentoring system appears to hold promise in terms of the development of a repertoire of essential practical skills and the reinforcement of positive attitudes. This intervention may potentially serve as a sustainable and viable mechanism through which the development of practical skills can be meaningfully fostered.

8. References

[1] www.examfear.com/files/00/45/2010-12-09-20-08-05.pdf, retrieved 30/5/2014.

[2] Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 393-441). NJ: Lawrence Erlbaum Associates.

[3] Wellington, J. (Ed.) (1998). *Practical Work in School Science. Which Way Now?* London: Routledge.

[4] Leach, J. and Scott, P. (1995). The demands of learning science concepts – Issues of theory and practice, *School Science Review*, *76*(277), 47–51.

[5] Murphy, P. and Qualter, A. (1990). Constructing gender - Fair science activities and assessments. Contributions- GASAT, Sweden.

[6] Lave, J. (1988). *Cognition in Practice.* New York: Cambridge University Press.

[7] Bennett, J. and Kennedy, D. (2001). Practical work at the upper high school level: The evaluation of a new model of assessment, *International Journal of Science Education*, 23, 97–110.

[8] Osborne, J. (1998). Science education without a laboratory? In, J. Wellington (Ed.), *Practical Work in School Science Which Way Now?* (156–173). London: Routledge.

[9] Hodson, D. (2001). *Research on practical work in school and universities: In pursuit of better questions and better methods*. Proceedings of the 6th European conference on research in chemical education. University of Aveiro; Aveiro, Portugal.

[10] Tamir, P. and Lunetta, V. N. (1981). Inquiry related tasks in high school science laboratory handbooks, *Science Education, 65,* 477–484.

[11] Lunetta, V. N., Hofstein, A. and Clough, M. P. (2007). Teaching and learning in the school science laboratory. An analysis of research, theory, and practice. In, S. K. Abell and N. G. Lederman (Eds), *Handbook of Research on Science Education* (pp. 393–431). Mahwah, NJ: Lawrence Erlbaum Associates.

[12] Lunetta, V. N. (1998). The school science laboratory: Historical perspectives and centers for contemporary teaching. In, P. Fensham (Ed.). *Developments and Dilemmas in Science Education* (pp. 169–188). London: Falmer Press.

[13] Braund, M. and Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out-of-school learning, *International Journal of Science Education*, 28, 1373–1388.

[14] Millar, R. (1999). *Understanding how to deal with experimental uncertainty: A 'missing link' in our model of scientific reasoning?* Paper presented at the conference of the European Science Education Research Association (ESERA), Kiel, Germany, August 31 – September 4.

[15] Dori, Y. J., Sasson, I., Kaberman, Z. and Herscovitz, O. (2004). Integrating case-based computerized laboratories into high school chemistry, *The Chemical Educator*, *9*, 1–5.

[16] Reiser, B. J., Tabak, I., Sandoval, W. A., Smith, B. L., Steinmuller, F. and Leone, A. J. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in Biology classrooms. In, S. M. Carver and D. Klahr (Eds) *Cognition and Instruction: Twenty-five Years of Progress*. Mahwah: Erlbaum.

[17] Kotze, A. (2005). Experimental Physics - Method and Theory.

[18] World Economic Forum – Global Competitiveness Report 2013 - 2014.