A scientifically efficient approach for uniform evaluation of Physics practicals using software embedded and improvisation-based system at Doornfontein Campus of the University of Johannesburg

Padmanabhan Nair, Jan Oelofse, Sam Ramaila and Leelakrishna Reddy

Physics Department, University of Johannesburg, Johannesburg, South Africa

E-mail: samr@uj.ac.za

Abstract. Physics practical work at universities is traditionally evaluated on the basis of a laboratory report of the activities characterising a particular experiment. This form of evaluation generally puts a learner under considerable pressure in view of the required language proficiency as an additional aspect considered during the evaluation of the report and for which penalties might be incurred. Hence, this article outlines how a Physics practical could be evaluated using software-assisted evaluation system based on a report which does not require language proficiency. The experimental report in this regard specifically encapsulates activities whose nature is described in terms of figures, graphs and drawings. The underlying theoretical knowledge associated with the experiment is provided as part of a detailed experimental procedure.

1. Introduction

Across the world, evaluation of laboratory practical work is traditionally based on the laboratory report which the students submit on completion of the practical. There is no academic control or supervision provided on report writing. In many instances, students are tempted to copy and paste material and data available from the internet and other sources. In this regard, plagiarism becomes an endemic problem characterising laboratory reports generated by the students. Moreover, traditional methods of evaluating laboratory reports are sometimes bedevilled by considerable subjectivity as opposed to objectivity.

2. A novel way of evaluating Physics practical work

A software-assisted marking system may potentially overcome most of the problems encountered with the traditional methods of evaluating laboratory reports. Evaluation software based on Microsoft Excel and supported by clearly defined macros is used for the marking of Physics experiments at the Doornfontein Campus of the University of Johannesburg. A data bank has been generated for each equipment and workstation as part of the permanent set-up process of the experimental arrangements. Wherever necessary, provision is made for improvisation in the use of standard equipment in order to make the experimental set-up versatile for purposes of accommodating graphical representations of obtained experimental results. The data bank is generated in such a way that the user (the student) can obtain unique experimental results from each workstation. This uniqueness serves to eliminate the chances of copying experimental results associated with other workstations.

3. The nature of the marking system

The computer software in the Data Analyser's Office contains the experimental data and the corresponding results for each unique laboratory workstations which are conveniently referred to as unique position numbers (UPN). Within a typical setting, students doing the practical in each of the UPN would obtain data which serves as input checked against existing data available in the database. The percentage variation for tabulated data and related graphs, if any, is quantified by the software and marks awarded accordingly. The software is reviewed yearly to ensure that the stipulated tolerance values are still relevant as effective monitoring tools. System-generated marks are indicated in the results books as feedback to students. Data capturing is administered by permanent laboratory staff. Updated mark sheets are published on a weekly basis using dedicated Physics notice boards. The evaluation takes the form of continuous assessment which occurs throughout the academic year.

4. Merits of the evaluation system

Merits of the evaluation system include features such as built-in tolerance which is an essential monitoring tool in many ways. The system allows for persistent errors due to faulty equipment at particular laboratory workstations to be detected for immediate attention and repair as well as the provision for compelling and continuous maintenance and development with the result that record-keeping is made easy and efficient.

5. Research studies on the efficacy of practical work in physics education

Discourse about the efficacy of practical work in physics education gravitates towards a considerable number of significant key considerations. For instance, one of the prevailing assertions points to the fact that laboratory work has found a central place in the teaching and learning of physics in schools and universities [1]. In addition, it has been assumed that laboratory experiences can make physics more real and illustrate the way physicists work in order to gain answers and offer insights into the physical world [1]. While practical work plays a significant role in helping students to make links between the domain of objects and observable properties, events and domain of ideas [2], laboratories are, however, expensive in terms of resources and working time [1]. In fact, declining resources at universities threaten to reduce the extent of experimental work in physics courses in the future [3] and South African universities are no exception.

Some of the key findings emanating from research studies on the role of practical work in physics education are worth mentioning in this regard: laboratory work improve students' practical skills and their ability to understand theory [3]; laboratory activities play a central and distinctive role in physics education [4]; for many students, laboratory work is mainly manipulating equipment but not manipulating ideas [4]; high expectations and low satisfaction with laboratory work [1]; the educational context hinders the implementation of practical work [1] and unclear place of laboratory work in physics studies [1].

Commensurate with considerations in this regard, the role that information technology can play in supporting teaching and learning in practical work is paramount. While significant changes in technologies have offered new resources for teaching and learning, insufficient attention has been directed to examine critically how these new technologies can enhance experiences in the laboratory [5].

6. Some typical examples of the marking format embedded in the software system

Figure 1 below shows a typical example of the marking format for Mechanics.

EXPERIMENTAL PHYSICS VERSION 6

Group		Pos Number	1	Exp Date	
Operator		Work Pos	1	Mark Date	2013/06/10 09:35

Start

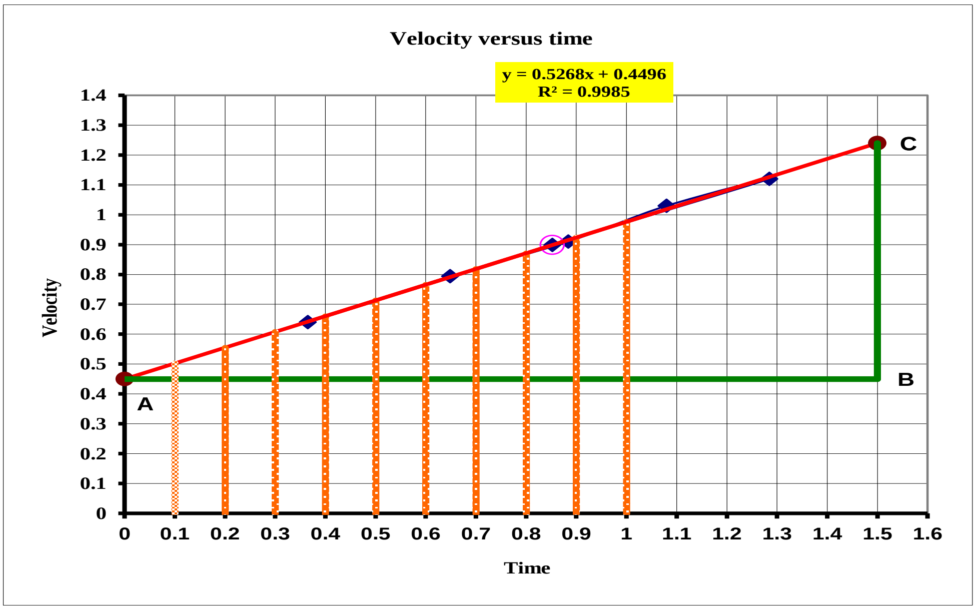
Position 1 Su

EXPERIMENT 84: Velocity versus time for constant positive acceleration

Results:

Gate 1 position (cm)	50	70	90	110	130	Mean
Time t (s)	0.365	0.649	0.884	1.080	1.285	0.853
Velocity v (ms^{-1})	0.64	0.794	0.91	1.03	1.12	0.899

	84	18
R	10	10
G	8	8
T	18	18



GRAPH CHECK LIST

Shown all points (blue)	y
Form as shown (red line)	y
Centriod (Pink)	y
Shown A	y
Shown B and C	y
Shown shaded area	y

ERROR MESSAGE

R	10	10
G	8	8
T	18	18

From the graph: (i) u = 0.448 ms^{-1} (ii) a = 0.53 ms^{-2}

(iii) s = 0.71 m

Please use "Back" button for main menu. Done **Data not Written !!**

Figure 1: Title of experiment: Velocity versus time for constant positive acceleration

A typical example of the marking format in relation to Current Electricity as a conceptual area in Physics is provided in Figure 2 below.

EXPERIMENTAL PHYSICS VERSION 6

Group		**Pos Number**	1	**Exp Date**	
Operator		**Work Pos**	1	**Mark Date**	2013/06/10 09:40

Start

Position 1 Su

Experiment 187: Unknown resistance by Ohm's law.

187 11

Multimeter 1: Milli-ammeter, use **black and green leads**, selector on 200 mA.

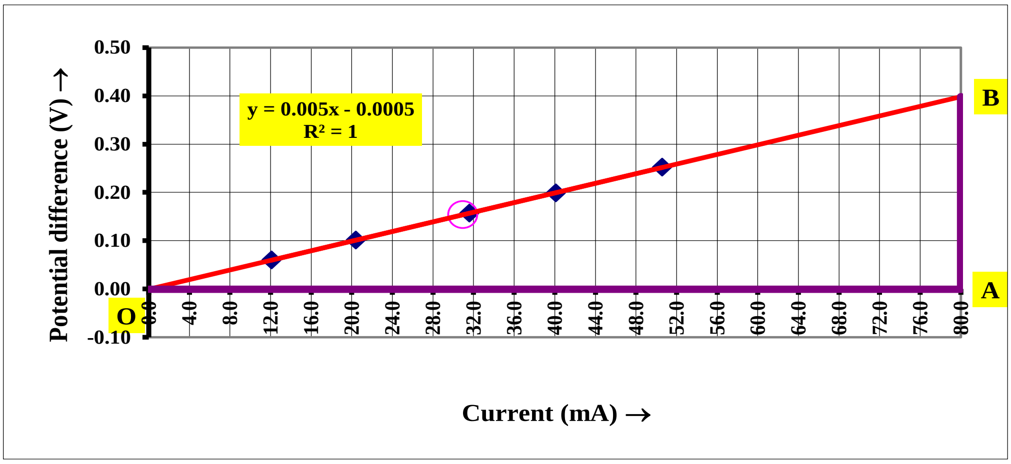
Multimeter 2: Voltmeter, use **black and red leads**, selector on 2 V.

Results: Use currents of approximately 10, 20, 30, 40 and 50 mA.

						Mean
Ammeter reading I (mA)	12.1	20.4	31.6	40.1	50.6	31.0
Voltmeter reading V (volt)	0.060	0.101	0.157	0.199	0.252	0.154
Unknown Resistance X (W)	4.96	4.95	4.97	4.96	4.98	4.97

R	5	5
A	2	2
G	4	4
T	11	11

Potential difference versus current



GRAPH CHECK LIST	
Shown all points (blue)	y
Form as shown (red line)	y
Centroid as shown (pink)	y
Shown point A	y
Shown point B	y

R	5	5
A	2	2
G	4	4
T	11	11

From the graph: The unknown resistance = AB/OA = **5.00** Ω

Please use "Back" button for main menu. Done **Data not Written !!**

Figure 2: Title of experiment: Unknown resistance by Ohm's law

An additional typical example of the marking format involving Geometrical Optics is depicted in Figure 3 below.

EXPERIMENTAL PHYSICS VERSION 6

Group		Pos Number	1	Exp Date	
Operator		Work Pos	1	Mark Date	2013/06/10 13:52
Experiment 43: Focal length of a convex lens by the lens equation.					

Start **Position 1 Su**

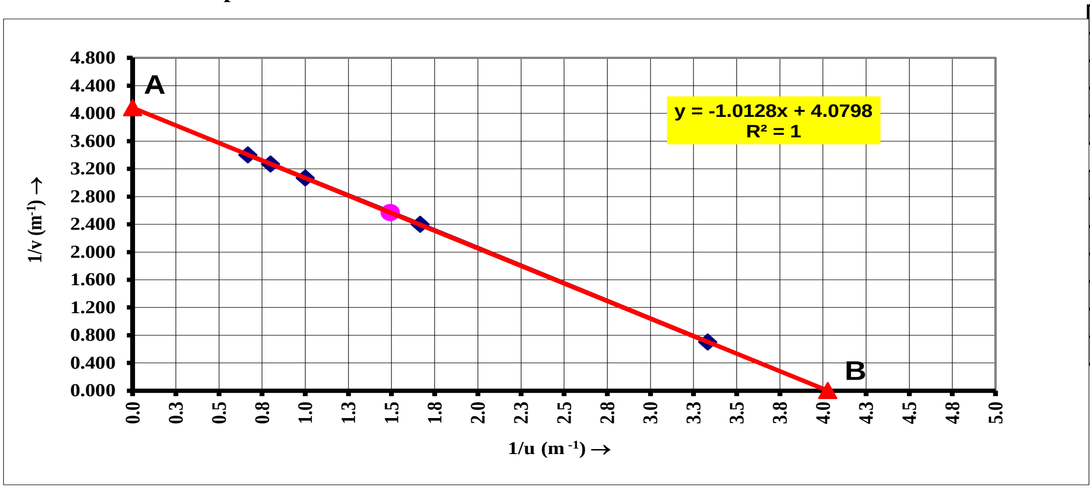
43 13

Results:

A u (m)	Screen pos B (m)	v (m)	1/u (m^{-1})	1/v (m^{-1})	1/f (m^{-1})	f (m)
0.300	1.725	1.425	3.333	0.702	4.035	0.248
0.600	1.017	0.417	1.667	2.398	4.065	0.246
1.000	1.326	0.326	1.000	3.067	4.067	0.246
1.250	1.556	0.306	0.800	3.268	4.068	0.246
1.500	1.794	0.294	0.667	3.401	4.068	0.246
		Mean	1.493	2.567		0.248

R	5	5
A	3	3
G	5	5
T	13	13

Graph of 1/ℓ' versus 1/ℓ for a concave mirror



GRAPH CECK LIST

Shown all points (blue)	y
Form as shown (red line)	y
Centroid (pink)	y
Shown A	y
Shown B	y

ERROR MESSAGES

R	5	5
A	3	3
G	5	5
T	13	13

From the graph: $1/f_A$ = OA = 4 m^{-1} $\Rightarrow f_A$ = 0.250 m and $1/f_B$ = OB = 4 m^{-1} $\Rightarrow f_B$ = 0.250

Thus the average focal length from the graph = 0.246 m.

Please use "Back" button for main menu Done **Data not Written !!**

Figure 3: Title of experiment: Focal length of a convex lens by the lens equation

7. Efficiency of the system

Table 1 below indicates the efficiency of the system during the first and second semester in 2012. Given that the number of students going through the Physics laboratories per week is about 2000 and the number of experiments done per student on average is 30, the number of experiments marked during the two semesters in 2012 is quite astronomical.

Table 1: Efficiency indicator of the marking system

	1st Semester	2nd Semester
Number of active students	1360	1520
Average number of groups per week	70	69
Number of experiments marked	24862	11812
Average marking time per experiment	40 seconds	45 seconds

8. Conclusion

By its very nature, the software system described has proved to be an efficient and innovative system over the years. In addition, it has provided the capacity needed for handling large volumes of practicals as a result of the high numbers of students. This software system also makes it possible for more practicals to be carried out in a sustainable manner.

9. References

[1] Vilaythong, T. (2011). *The Role of Practical Work in Physics Education in Lao PDR.* Unpublished Doctoral Thesis, Department of Physics, Umeå University, Sweden.

[2] Millar, R. (2004). *High School Science Laboratory: Role and Vision*. National Academy of Science, Washington, DC.

[3] Hanif, M., Sneddon, P.H., Ahmadi, F.M.A. & Reid, N. (2009). The perceptions, views and opinions of university students about physics learning during undergraduate laboratory work. *European Journal of Physics*, **30**, 85-96.

[4] Hofstein, A. & Lunetta, V.N. (2003). The laboratory in science education: Foundations for twenty-first centuries. *Science education*, **88**(1), 28-54.

[5] Lunetta, V.N., Hofstein, A. & 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.