A SOFTWARE-BASED PHYSICS PRACTICAL MARKING SYSTEM-NOVEL APPROACH TO SCIENTIFIC ASSESSMENT OF PHYSICS PRACTICALS

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ABSTRACT: The Applied Physics and Engineering Mathematics Department of the University of Johannesburg offers altogether 25 Physics modules to the faculties of Science, Engineering and Health Sciences with the total number of students involved per week in 2015 is around 2000. The weekly marking of laboratory reports of Physics practicals becomes a nightmare considering the voluminous of manual marking and timeous publication of results if it is done in a traditional way. To circumvent this problem, a software-embedded making system using excel-rubric is employed. Excel programs are used as a basis for comparing original data of each experiment for each experimental station stored in the computer system to that of the students' reports on the experiments done. The system is programmed to award marks based on the students' understanding of the practicals, manipulation of data, accurate plotting of graphs and interpretation of graphical and tabulated data and ultimately the accuracy of the results obtained in relation to the pre-loaded data. The loading of student data into the system and the corresponding system-generated marks are captured by the services of just two Data Capturers attached to the laboratory. The efficiency of the system lies in the fact that, for example, 40 laboratory reports can be marked in less than an hour, thereby saving lecturing staff, time and stationary. Comparing the traditional method with its inherent subjectivity, this novel method has a technological edge and yields a faster evaluation process based on objectivity. Moreover, the system reduces the burden of lecture overloads. The results of an attitude survey conducted among students testify the success of this unique assessment system. National and international Programme accreditors of Engineering qualification programmes have applauded this marking system and laboratory set-up on several occasions.

Keywords: Physics practical software, traditional, novel, marking and laboratory

1. INTRODUCTION

Currently the use of a computer soft-ware or any other technology related system for the evaluation of physics practicals is highly lacking. At the same time, literature suggests that marking of physics practicals is a highly subjective area, with no 2 examiners or markers are able to consistently agree on the final mark for a practical report. Due to the unreliability of this marking system, it was decided that we introduce an innovative marking system that would consistently yield the same marks, irrespective of who the marker was.

In this respect, this article will focus on the efficacy of laboratory practical and more importantly the usefulness of a unique Excel Rubric Marking Programme (ERMP). The Department of Applied Physics and Engineering Mathematics at the Doornfontein Campus of the University of Johannesburg is offering Physics as a service course to diploma programmes in the faculties of Engineering, Health and Science. The curricula prescribe 30-40 experiments per semester semester for these diploma programmes, which forms a Practical Module in addition to the Theory Module (Kotze, 2005). The student must register for each of these modules separately. The numbers of students in these programmes are in the range 150-200 for which practicals are conducted in 7 dedicated Physics Laboratories having 24 student work stations (cubicles) and roughly 2000 students per semester

attend these laboratories. The students are provided with a Theory and Method Book illustrating each experiment in relation to the set-up in the laboratory and a result book for recording the results of the experiments, designed and developed by the Department. This laboratory set-up can be regarded as a unique instructional environment (Domin, 2007) for which student-centered learning is fostered. Further, it can be said that it shares similar goals and objectives in which it "allows students to engage in processes of investigation and enquiry" though a deductive approach (Domin, 2007). This unique set-up is also linked to an exceptional assessment system that differs from the traditional way in which practicals are assessed at most universities in South Africa and abroad.

Since over 2000 learners do the experiments and this leads to over 2000 reports that have to be evaluated within a week to avoid a backlog. The marking of such large volume of students' practical reports containing experimental results, traditionally requires the services of a large number of academic staff. Thus effective assessment of laboratory practicals can be a challenge if such large numbers of reports have to be marked in a week. To reduce the working and administrative load of lecturers in this situation, whilst at the same time ensuring the best quality output, a new method of assessment, utilizing a computer aided software system, the first of its kind in South Africa, is employed. Its merits are discussed from the perceptions of a questionnaire administered to the students. This anonymous survey elucidated opinions from the students about the assessment methods and its efficacy. In addition to this a face-face interview was held with students on and had an ad hoc basis to get their perceptions of the marking system. The purpose of this paper is to highlight the need for an alternative assessment system for the many modularized programmes offered by the department for large cohorts of students. Further, this system was designed to ensure consistency in the evaluation of practical reports. This is an ideal proposition for Higher Education institutions particularly for service offering departments where lecturers have high lecturing work commitments and the need for them to advance their research niche areas in keeping with excellence in teaching, learning and research.

2. EVALUATION FRAMEWORK FOR MARKING USING A SOFTWARE APPROACH

The following framework provides salient issues that need to be addressed for administering an efficient and reliable software-embedded marking system.

Key issues (Heinrich, 2012)	Description
1. Marking rubric	Software excel programme designed with key features from a full laboratory report write-up
2. Administration of student reports and marking	2. Two data capturers take full responsibility for the marking process and manual capturing of marks. Students' marks are saved in the system and can be accessed by the administrator as required. Marks in the system are saved for a period of in access of 10 years.
3. Consistency and reliability of marking	3. Tried and tested memorandum has been fed into the software system. Students' data are compared to the background memorandum which is similar to a "pre-inputted model answer" (Sheader et al., 2006). Each data point has a tolerance value and adjusted from time to time for consistency.
4. Marking feedback	4. Marked reports are returned within days with comments made by the markers and marks are displayed on the noticeboard (with summative

	marks in the spreadsheet) for tracking of progress. Such feedback keeps the students motivated and interested. Students are given an opportunity to review their marks if needs be. At risk students are easily tracked and given additional coaching by lecturers and tutors.
5. Moderation of reports	5. Head of the laboratory division is charged with the responsibly of moderating reports for quality control and for consistency checks.
6. Reflections of marking	6. When laboratory reports are returned, lecturers are also given an opportunity to check various features that supports consistency and reliability of the whole marking process. They too have an opportunity to query how marks are awarded. Students also reflect on the marks they obtained and its justification.
7. Additional aspects about the practical work	7. If for some reason students are absent, they need to supply strong evidence for such absence to be exempted from that particular practical. Only the head of laboratory can grant that exemption. Deadlines for submission of reports are pre-set at 10 AM on a certain day of the week; late submissions get the harshest penalties in terms of marks they are awarded per practical session.
8. Additional support	Lecturers are available on a daily basis for consultation. Students are given an opportunity to check their work with the lecturer concerned before final submission. Additional support is also provided by the laboratory technicians, who are always on standby for immediate repair of a damaged system.

3. METHODOLOGY

In each practical session the lecturer demonstrates the experiment/s and thereafter the students carry on with their experiments independently in their individual laboratory positions (cubicles). The students submit their completed Results Books to the laboratory office weekly for assessment of the practical they have done. The assessment is done through a unique software-based marking system, employing Excel IF functions (which gives a range of permutations for a particular reading and differentiates between a correct and incorrect answer) spreadsheet with a feasible range of values for a particular quantity as well as Visual Basics for graphical evaluations. This operating system is designed to compare the original memorandum (from pre-inputted) data of each experiment stored in the data bank (background) to the student's data obtained from individual practicals (captured by the data capturer). The layout of the Excel Rubric marking programme is shown in Figure 1, below. The concurrence or variations are shown by the software and marks are awarded accordingly by the system. Displays of a blank answer sheet with pre-loaded values are in shown in Figure 2, below. Typical student answer sheets with marks are shown in Figure 3, obtained from memorandum that is stored in the data base, as displayed in Figure 4 below. The marks students get on a weekly basis are

published weekly that forms part of a Continuous Assessment Strategy System (CASS). Merits of this evaluation system are tracked though perception response of a carefully designed survey questionnaire. The efficiency of the system is reflected in the number of practical reports that are assessed per semester. For the purposes of safety and accountability (and quality) only lecturers are responsible for conducting the experiments. The Method Book is a fully inclusive book that contains all the procedures and theories on the practical and its set-up. Junior lecturing-staff are given intensive training on the use and procedures to be followed in the laboratory. Specially trained technicians are on standby for immediate repair to the system, if any operation goes wrong. Maintenance and replacement of consumable comes at a high cost (due to high usage) which has to be borne by the department.

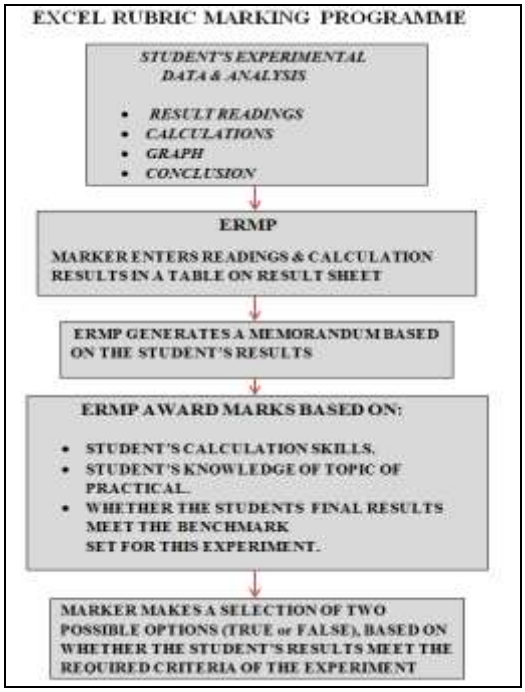

Figure 1: Summary layout of marking process

3. DISCUSSION

The different stages in the Excel Rubric Marking Programme is illustrated in the following sequence of stages involved in conducting the experiment, recording of results, performing necessary calculations and the submission of the report (completed data analysis) are shown below.

Stage 1: A blank result sheet with pre-programmed values for which the experiment need to be carried out is shown in figure 2 for a typical experiment "Luminous intensity using Lambert's law". Students need to collect the data and fill it in the grey regions of the table, while the white regions are reserved for calculations which they need to do at home. In the final presentation, a report that includes graphs, calculated values and a conclusion of the experiment need to be done before submission.

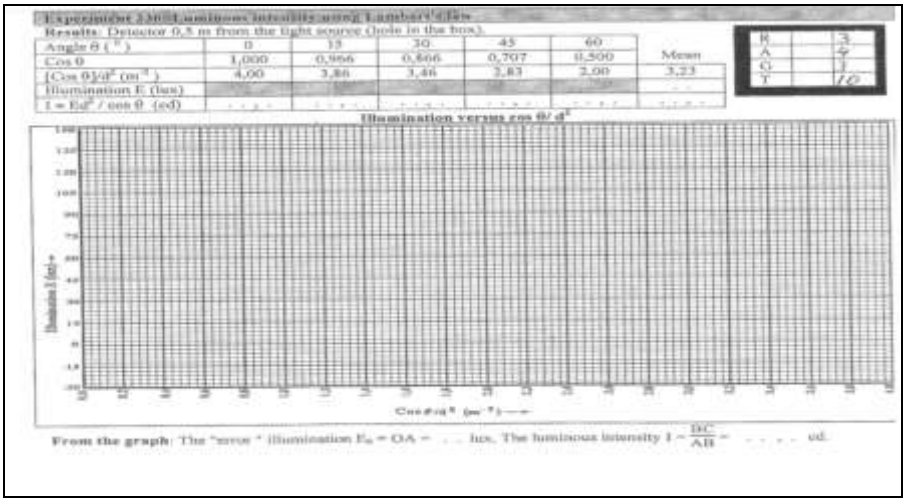

Figure 2: A blank answer sheet with pre-loaded values

Stage 2: Students perform the required calculations of the recorded results and plots the necessary graphs on the supplied graph sheet which is then submitted before a certain time deadline (usually a week) as per a programme schedule. A post-box type facility enables students to submit the result book which remains open on a 24 hour cycle. The results of each practical session are published weekly on the notice board for tracking of progress. If the students are unhappy about their marks or need justification, they are free to consult with the data capturers/markers.

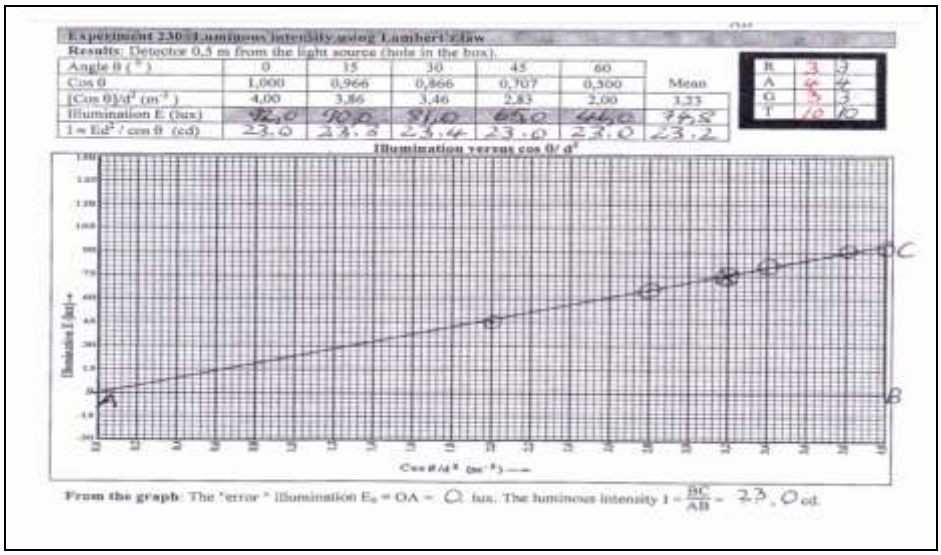

Figure 3: A typical student-completed result sheet

Stage 3: The data capturer uploads the student's data (this data is manipulated by the computer soft-ware to generate the students' output) into the master ERMP data for comparison. For example, if the student-generated graph from the experiment exactly coincides with the original graph in the data bank of the Excel Rubric Marking programme (ERMP), the student is awarded by the system a full score for the graph. If there is more than 10% variation, a reduced mark will be awarded by the system depending on the merit of the case. The function of the marker is to make a

selection of possible options, true or false, based on whether the students' inputs meet the criterion of the experiment.

Some important conclusions have emanated from the marking of graphs:
1. Students are able to correctly plot a graph from the data but are unable to interpret the physics principles associated with such a behaviour.
2. Students persistently struggle to determine the gradient of the graphs from the existing data.
3. Students are able to plot a linear graph according to what is typically expected for such an experiment. The system is able to distinguish between correct and incorrect data and thus they get low marks for accuracy. This concept would not be easily picked up from other systems of evaluations, thus leading to inconsistency in marking of practical reports.

A discussion of the master marking sheet which serves as a memorandum for comparison and evaluation is shown in Figure 4 below. A pictorial representation of the laboratory set-up of Lambert's Law is shown in picture 1 below:

Picture 1: Laboratory set-up of Lambert's Law

From this picture, the light source is at a distance of 0.5m and the intensity values are measured for various angles of theta from 0 degrees to 60 degrees. This system is linked to a lux meter which is not shown in the diagram above. When readings are taken, a door that encloses this system is shut to avoid any outside light from interfering with the measurement of light.

Below is a table that explains each step in the marking memorandum that forms part of the software to mark the students' practical reports.

EXPERIMENT NUMBER 230: Luminous intensity using Lambert's Law									
DATE									
GROUP								MARKS	
LAB									

POS:									
A	B	C	D	E	F	G	H	I	J
Formula in the software: IF (F1 > E1/D1, “FALSE’, F1 < E1/D1, “FALSE”, “TRUE”)									
	ANGLE θ (^{0})	**Cos θ**	**Cos θ/d^2 (m^{-2})**	**Illumination E (lux)**	**Intensity I (cd)**				
1	0	1.000	4.000	92.0	23.0		TRUE/FALSE	0.5/0	
2	15	0.966	3.860	90.0	23.3		TRUE/FALSE	0.5/0	
3	30	0.866	3.460	81.0	23.4		TRUE/FALSE	0.5/0	
4	45	0.707	2.830	65.0	23.0		TRUE/FALSE	0.5/0	
5	60	0.500	2.000	46.0	23.0		TRUE/FALSE	0.5/0	
6		Mean	3.230	74.8	23.2		TRUE/FALSE	0.5/0	

According to the table, pre-loaded values are given in columns B, C and D for a range of measurements. Students will record the values in columns E-1 to E-6. They do the necessary calculations, according to the formula: I = $\frac{E}{cos\theta} d^2$ (which is derived in the text), where d is fixed at the value d = 0.5 m from the light source and E is the reading on the lux meter, which the students use to determine the values in columns F-1 to F-6. The accuracy of these values is determined according to a pre-loaded formula in the software: IF (F1 > E1/D1, “FALSE’, F1 < E1/D1, “FALSE”, “TRUE”). From this formula, for example, if the student obtains a value of 23.0 in column F1, the student gets a “TRUE” option and is awarded 0.5 marks (maximum). Note that the value in columns F is the ratio of columns E is to D. On the other hand if the student gets less than 23.0 or greater than 23.0, the student gets a “FALSE” option and is awarded 0 marks. A further formula is loaded for this purpose: IF (H1, 0.5, 0). Likewise F2, F3, F4, F5 and F6 are similarly determined. In columns I-1 to I-6 are the marks students will get, according to a TRUE or FALSE option (written in green, as colour-coding is used for different options). Getting all the answers correct in columns F1 to F6 will gain a maximum of 3.0 marks out of a total possible 10 marks for the whole experiment. The rest of the marks are obtained from plotting of the graph and arriving at a correct conclusion in the verification of the correct principle.

From all the data collected and correctly manipulated, as indicated in columns E and F, the student then plots the graph of x (Cos θ/d^2) versus y (illumination E) (see graph below, figure 4) in the graph sheet provided. For the plotting of this graph, the students are awarded a maximum of 3 marks which are distributed as follows:

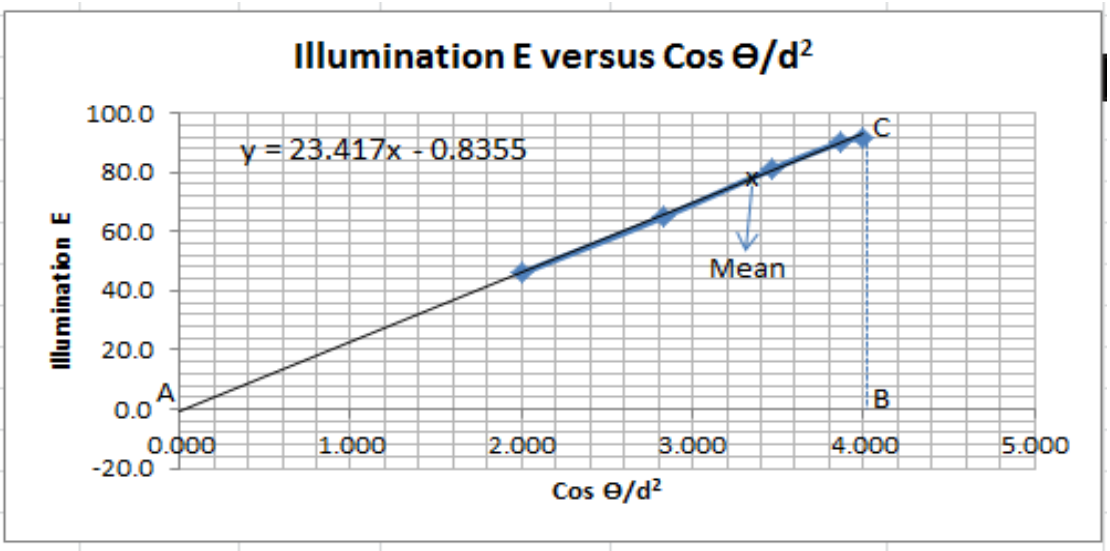

Figure 4: Graph of Cos θ/d² versus illumination E

1. **Showing all points on the graph:** Plotting of all data points on the graph will yield the student a maximum of 0.5 marks, otherwise a 0 mark. Likewise an option of TRUE or FALSE is awarded by the data capturer through a visual examination of the graph. This can be seen from the excerpt of the excel marking memorandum sheet:

   Show all points on graph TRUE/FALSE 0.5/0

2. **Showing the mean value on the graph:** If the student correctly obtains and plots the mean value (ringing it) on the graph, they can obtain a maximum of 0.5 marks, otherwise a 0 mark. The TRUE and FALSE option also applies here. Excerpt from excel marking sheet is shown below:

   Show the mean on the graph TRUE/FALSE 0.5/0

3. **Show all labels on graph:** For this, the student draws the line graphs and labels it accordingly as A, B and C, as can be seen on the graph. Correct labelling of the graph earns the student a maximum of 1 mark, otherwise a 0 mark. The correct labelling of the graph is significant in determining the gradient of the slope. In this case a TRUE and FALSE option is applies. Excerpt from excel marking sheet is shown below:

   Show labelling on the graph TRUE/FALSE 1.0/0

4. **Show graph is a straight line:** In this case, the student will have to draw a least squares fit through the data points. The permutation of drawing this straight line is many because of the scattering nature of the data points. The closest fit to the real graph will earn the student a maximum of 1 mark, otherwise a 0 mark. The TRUE and FALSE option applies here as well. Excerpt from excel marking sheet is shown below:

   Show graph is a straight line TRUE/FALSE 1.0/0

In addition to the above, marks are also awarded for the conclusion part of the experiment. The background illumination is obtained from the regression line, $y = 23.417x - 0.8355$, where the student has to take the correct value of 0.8355 lux = EO = OA. This value earns the student a maximum of 2 marks. Finally, the gradient (luminous intensity) of the straight line is obtained from the ratio: I = BC/AB = 23.4 cd. This value earns the student a maximum of 2 marks.

This qualitative-cum-quantitative evaluation of laboratory practicals through the software embedded approach has received positive feedback from lecturers, students and international accreditors compared to rudimentary ways of assessing practicals in most traditional ways at universities. The system as highlighted above provides for a quick and accurate way to capture marks and for tracking of weekly progress of students. Other ways of evaluation must be time-consuming, coupled to voluminous use of paper in terms of lengthy practical-write ups. In this technological age, a faster return of reports and immediate feedback on reports keeps the students interested and fully engaged in the programme. A similar system was used for evaluation of assignments by Heindrich et al, using Lightwork incorporated software. That study showed that Lightwork software system was "well suited to support efficient, high quality assignment marking".

The following represents the questionnaire survey administered to 74 students from different fields of study to track the merits of the evaluation system. These questions were circulated among senior staff for feedback and comments before a final set of questions were decided. A summary of the survey is given below:

SURVEY QUESTIONNAIRE

Perceptions of the evaluation format of the Physics Practicals. Answer yes or no to each of the following questions.

1. Do you understand how your practicals are assessed?
2. Are you satisfied with the way your physics practicals are assessed?
3. Would you prefer to write a full report of the experiment you did instead of being assessed this way by filling up answers in the Result Book?
4. Do you get laboratory reports back on time?
5. If you are not satisfied with the results, are you given an opportunity to review it?
6. Are you given adequate time to complete your practical reports?
7. Do you think that the markers are very strict in their marking without providing any range value for the answers?
8. Marks are awarded for taking readings, accuracy of the readings, graphs, etc. Do you understand how marks are allocated for each of these parameters?
9. As practical weeks pass by do you get used to the system and prepare accordingly?
10. Do you think this system of assessment is good and you would recommend it to any students doing physics practicals?

Students are given a dichotomy of either choosing yes or no to each of the questions listed above. The results of such a survey are given in the table 1 below, showing the percentage of students opting for the "yes" or "no" answers for each question.

QUESTION	% of students choosing the yes option	% of students choosing the no option
1	70	30
2	55	45
3	11	89
4	84	16
5	53	47
6	84	16
7	45	55
8	57	43
9	78	22
10	84	16

Table 1: Summary of results from the survey questionnaire

From this survey it became very clear that many students were affirmative in their responses and displayed high level of confidence in preference of the software marking system as a method of assessment. It is overwhelming to see that 89% of the students would not prefer the traditional way (also for those that were used to the way practicals were assessed in school) that Physics practicals are offered by most universities in South Africa and abroad for students engaged in undergraduate physics studies. As a service department, roughly 2000 practicals are marked per year and students are impressed by the fact their marked reports are returned timeously thereby appreciating the efficacy of the software guided marking system. In respect to question 7, for which the students felt that, the markers were a bit strict in their marking. In response to this question it must be mentioned that every question has a tolerance range which was determined by us (lecturers) performing the experiment many, many times to find an optimal solution range from the standard deviation. This may be unknown to the learners but it is necessary condition for a software embedded marking system to quantify the awarded marks. However, it must be further mentioned that due the aging of the system, these tolerance values are from time to time adjusted. This only happens when whole class does badly thus imploring us to intervene and rectify the situation through moderation of the reports. The grid in Figure 5 shows a mini template of how marks are allocated per item, as given below (further explanation is given later in this paper):

Reading	X
Accuracy	X
Graphs	X
Total	X

Figure 5: Marks allocation to different sections of an experiment

In question 8, students have answered 57 % in favour of how these marks were obtained. Initially the students may be totally confused of how these marks are allocated but as weeks pass by (lecturers and markers constantly reminding them of the procedures and pitfalls of the marking system) they get more accustomed to the functionality of the marking system and perform better. In each subsequent report students are challenged to perform better. Students work in individual cubicles, and we have differentiated the memorandum in each of the 24 allowed cubicles thereby not allowing any student to copy other students' work, giving us easy eradication of plagiarism. If in a rare case it happens, students may get some marks for random readings but for accuracy they get

zero. Each batch of reports is marked (computer-guided) by a single marker for consistency purposes. The purpose of doing this is to deter them from such malpractices and that they should take ownership of the practical work. Also, any alteration of readings in the grey region of their result book must be countersigned by the lecturer in charge. If a student decides that his/her readings are inaccurate and attempts to cancel his/her recorded reading in favour of his/her friends' reading, without being countersigned by the lecturer while in the laboratory, will automatically awarded a zero mark. This seems harsh but the students get used to it. Their response to question 10 is most encouraging student perception, which recommends the efficacy of the Excel Rubric marking system. We are at present in the process of modifying the system to make way for more advanced experiments. At present we are offering in excess of 350 undergraduate experiments that is linked to software embedded marking system, that is housed in seven dedicated laboratories, specialising in Mechanics, Heat and Temperature, Physical Optics, Geometric Optics, Kinematics, Electricity and Radioactivity. We will be offering a new 4 year degree in Applied Physics in 2016, for which the state of the art experiments were purchased to cover topics such as renewable energy, nanotechnology, optics and optoelectronics and spectroscopy. These experiments will have to be installed and experimental trials need to be done to feed the software system with a possible memorandum (similar to Figure 4) for the purposes of marking.

TABLE 2: EFFICIENCY OF THE MARKING SYSTEM

This table contains the various Physics groups and the lecturers that are responsible for that particular group. Further, other details such as the number of periods, the number of active students in the system, the pass rates, the average percentage per class and the marking time per group are highlighted.

NO	GROUP	PERIODS	ACTIVE	PASS	PASS RATE %	AVERAGE %	MARKING TIME (HR)
1	HOM A	1	16	16	100	69	6.676
2	HOM B	1	15	14	93	69	6.271
3	CHIRO A	1	20	20	100	79	7.952
4	CHIRO B	1	20	20	100	73	7.825
5	CE2 A	2	12	12	100	74	7.113
6	CE2 B	2	12	12	100	71	4.152
7	CE2 C	2	13	13	100	67	7.494
8	CE2 D	2	14	14	100	74	8.579
9	CE2 E	2	12	12	100	71	8.599
10	BCA	1	24	23	95.8	60	9.943
11	BCB	1	20	15	75	55	8.811
12	BCC	1	21	21	100	68	10.629
13	BCD	1	24	23	95.8	61	10.836
14	EXT2 A1	1	20	18	90	68	2.519
15	EXT2 A2	1	20	20	100	75	3.446
16	EXT2 B1	1	17	17	100	76	2.024
17	EXT2 B2	1	18	17	94.4	66	2.406
18	EXT2 C1	1	20	19	95	77	2.000
19	EXT2 C2	1	22	22	100	72	3.080
20	EHA	2	18	18	100	69	5.045

21	EHB	2	18	18	100	71	5.025
22	EHC	2	19	19	100	77	5.468
23	EXT MEC A	1	22	20	91	62	4.418
24	EXT MEC B	1	30	26	86.7	59	5.810
25	EXT IND A	1	20	18	90	56	4.253
26	EXT IND B	1	19	17	89.5	65	4.278
27	EXT IND C	1	20	18	90	64	4.402
28	EXT IND D	1	20	17	85	56	4.569
29	FP MECH A	1	21	18	85.7	65	3.014
30	FP MECH B	1	23	19	82.6	56	2.013
31	FP ELEC A	1	22	21	95.5	61	1.448
32	FP CIVIL A	1	15	15	100	71	1.472
33	FP CIVIL B	1	17	17	100	68	1.817
34	FPINDUS A	1	21	19	90.5	60	1.142
35	PF INDUS B	1	19	17	89.5	55	1.063
36	PF INDUS C	1	19	16	84.2	51	1.251
37	PFINDUS D	1	19	17	89.4	52	1.278
38	ELEC ENG A1	1	15	15	100	76	3.015
39	ELEC ENG A2	1	22	22	100	76	3.723
40	ELEC ENG B1	1	17	17	100	74	7.701
41	ELEC ENG B2	1	16	16	100	85	3.413
42	ELEC ENG C1	1	15	15	100	72	3.353
43	ELEC ENG C2	1	49	49	100	73	4.061
44	EXT ENG MET	1	49	49	100	73	11.283
	ALL	52	855	811	94.85		

According to the above table, a total of 52 periods were used in the second semester (generally a relatively quiet semester because of semesterised programmes) of 2014 for which the system was able to successfully mark 811 Laboratory reports, generating an average of pass mark of 94.85%. In general, the first semester for which most of the semester programmes are offered, constitutes the biggest of the physics practical offerings. Numbers in excess of 1000'–students register for the Physics practical modules, which have to be separately passed apart from theory. In total we could roughly have 2000 students per year engaged in Physics practicals. Of particular interest, it has taken our data capturers approximately 41.259 seconds to mark a laboratory report, thereby highlighting the efficiency, turn out time and thereby the efficacy of the marking system. Traditionally, in most universities in South Africa and abroad it would take on average at least 15 to 20 minutes to mark a lengthy laboratory write-up. This system is devoid of a lengthy write-up of the methods and procedures that the student has to follow to conduct the experiment. All these procedures are highlighted in the Method book and no need to repeat them verbatimly in their reports. It must however, be mentioned that that a skill such as observation skill which is not measured directly by the software system, is encompassed in the way the student records his/her observations correctly

and accurately from the unique experimental set-up. The student should be concerned primarily about the accuracy of the data that he/she collects to verify a known principle by following a deductive approach. However, other approaches of conducting practicals are followed in parallel to this in order to obtain the best way of conducting a practical. In this respect, a problem-based approach and the traditional expository based approach is followed for the same experiment. The efficacy of both approaches is tested through questionnaire surveys. In most surveys we conducted, students recommend their preference for the computer guided marking assessment. This system bears similarity to the assessment undertaken by Heinrich *et al*. (2012). This system of approach is most inspiring for first year students due to the lack of functional laboratories in most school in South Africa. The consequence of such a deficiency will produce un-prepared scientists for shaping the future of a developing country.

4. CONCLUSION

The use of the Excel Rubric marking system is a novel and an alternate way to assess physics practicals especially if there are large numbers of practical to be assessed. Its efficiency, reliability and accuracy are testament of the number of practicals that are assessed per semester. Further, a total of 30 300 are marked in a relatively short period of time (roughly I practical book per minute and cumulatively and more than 100 books per day) with minimal student query. The system is able to handle hundreds of data with relatively easy result-generation. A lot of stationary (abridged report for collection of data and report writing-compliant with soft-ware requirements) is saved and most importantly it is devoid of subjectively of an examiner. The students' perception from the survey questionnaire highlights their support for the assessment/evaluation system and this gives us an opportunity to further develop the system in keeping with technological advancement. In the near future it is envisaged that each student will be given a unique password to access the data bank and upload their results in the system, or they could answer the various practical questions on-line in their own leisure time (with a set deadline thereby allowing students to edit online before final submission). This type of assessment system will lessen the burden of staff in terms of academic administrative obligations. The many advantages of the computer aided system for the evaluation of practicals can outweigh the disadvantages in terms of it's "ability to spot plagiarism, effortlessly allows anonymous marking, and substantially reducing staff marking time" (Sheader *et al*., 2006). Notwithstanding the need for an alternate assessment system, the stark reality is that due to ever increasing student numbers, lecturer work commitments for research and the necessity to publish, the solution inherent in our model may be the way for Higher Education institutions should replicate in the future. The research gone into the system in its continued development and the subsequent ongoing monitoring, evaluation and modifications makes it a model worth emulating.

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