

Chapter #8

UNDERGRADUATE PHYSICS PRACTICALS AT THE UNIVERSITY OF JOHANNESBURG: A SURVEY ON STUDENTS' PERCEPTIONS

Leelakrishna Reddy

Department of Physics, University of Johannesburg, South Africa

ABSTRACT

For the conductance of physics, practical use was made of one of the seven technologically enhanced laboratories. These laboratories are designed to offer some 350 undergraduate experiments. A unique software-embedded system, the first of its kind in South Africa, was used to assess the students' results. Once the students submit their results, these are captured by the data capturer, fed into the software system, and simulated for comparison with the background readings. To appreciate the scientific value of these experiments and its offerings, a modified questionnaire, developed by Deacon & Hajek (2011) has been used. The questionnaire survey has been administered to 100 first year university students. A Likert-type scale from Strongly Disagree to Strongly Agree was used to analyze the results. The framework used for this study was taken from the work developed by the American Association of Physics Teachers (AAPT), which highlights goals to be achieved in a physics laboratory. The results of the survey revealed at least four factors that contributed to a positive perception to the value of the lab practicals. They ranged from the labs contributing to their knowledge, understanding, skills and enjoyment of the practicals.

Keywords: laboratory, software, practicals, value and experiments.

1. INTRODUCTION

According to Deacon & Hajek (2011), the perception of the value of physics practicals refers to an “enhancement” of the students' knowledge, skills abilities and other attributes that they acquire from an educational laboratory experience. This idea is also echoed by Freedman (2002) who says that laboratory experience improves one's knowledge of concepts and the various principles that are involved in an experimental investigation. So, what does laboratory work entail? It is said that laboratory work is the subset of all activities such as demonstrations, hands-on activities and activities for the attainment of other skills such as analytical and practical skills (Kirschner & Meester, 1988; Deacon & Hajek, 2011). Besides these activities, von Aufschnaiter and von Aufschnaiter (2007) say that laboratory activities should entail the development of concepts rather than finding the relationship between theory and practice. Some believe the aim of practical work is to “get the correct result” regardless of the way it is obtained (Emson, 2013), while many students argue that it is possible to complete experiments without a sound understanding of the physics concepts and equations (Hu, Zwickl, Wilcox, & Lewandowski, 2017). Researchers such as Shah, Riffat, and Reid (2007) have found their students to have a positive attitude towards laboratory work but they complained that the laboratory work lacked clarity in its purpose (Emson, 2013). Therefore, to improve the value of practical work with respect to its intended purpose, there is a need to develop a deeper

understanding of the knowledge of the procedural processes involved in the practical work (Pekmez, Johnson, & Gott, 2005). Thus, to improve the attitude of learners and the value of practicals, teachers need to have a clear understanding of its intended purpose as well as a sound understanding of the method of delivery of the practicals (Emson, 2013). Other researchers such as Hanif, Sneddon, Al-Ahmadi, and Reid (2009) view practical work as the development of both analytical and problem-solving skills. For a more holistic view of the laboratory skills, Elawady & Tolba (2009) have stated that there are four skills that are necessary for such a development, which are Conceptual understanding, Design skills, Professional skills and Social skills. The American Association of Physics Teachers (AAPT, 1998) has postulated similar goals for effective learning in the laboratory. A well-developed laboratory with well-crafted activities can make laboratory experiences for students enjoyable and interesting (Deacon & Hajek, 2011). Others such as Fraser, McRobbie, & Giddings (1993) have highlighted the following factors for student satisfaction: Student Cohesiveness (this factor describes how well students each and support each other), Open-endedness (this factor gives students opportunities to design their own research), Integration (this factor considers the integration/alignment between theory covered in class to the practicals offered in the laboratory), Rule Clarity (this factor describes how order and discipline is maintained in the laboratory) and Material Environment (this factor describes the adequacy of the laboratory to offer the stipulated practicals) (Luketic & Dolan, 2013).

To our knowledge, there is no literature that explicitly uses a software system to assess data collected from physics practicals. In most cases, practical reports are marked manually using some rubric system. Here at the University of Johannesburg we have patented a system that will be able to assist in assessing practical reports. However, it must be mentioned that there is sufficient literature on the use of technology in physics and in particular in the teaching and learning of the subject. The use of technology in the instruction of physics can be seen in the work of Ramma, Bhoola, Watts, and Nadal, (2018).

The University of Johannesburg makes use of seven dedicated technologically advanced laboratories for the conductance of practicals. Each laboratory, which focusses on different domains in physics, is comprised of twenty-four identical cubicles. The results of each experimental station are linked to a computer software system, which allows for easy and efficient marking of voluminous reports. In the context of the above, we consider the perceptions of the students towards the value of physics practicals through analysis of a survey questionnaire and to find factors that could contribute to positive satisfaction about their laboratory experiences.

2. RESEARCH QUESTION

This research is underpinned by the following research question:

What factors can be considered to contribute to a positive perception of the value of practical work?

3. CONCEPTUAL FRAMEWORK

This study made use of a framework, which recognizes five goals that are important in promoting effective learning in a laboratory. Such goals as promulgated by AAPT (1998) are:

(a) **The Art of Experimentation:** This goal allows for the engagement of each student in attaining significant experiences from the various experimental processes in the laboratory.

(b) **Experimental and Analytical skills:** This goal helps the student to develop basic skills in experimental physics as well as the skills necessary to do data analysis.

(c) **Conceptual Learning:** This goal helps the student to master the basic concepts in physics.

(d) **Understanding the Basic knowledge in Physics:** This goal helps the student to understand the role of observation in the laboratory and to distinguish between inferences that are based on theory to that from outcomes from experimental investigations.

(e) **Developing Collaborative Learning skills:** This goal helps the student to develop collaborative learning skills that are essential for success in their future life.

4. METHODOLOGY

4.1. Participants

A survey has been administered to 100 students that were engaged in a physics disciplined study at a South African university. These students were aware that the survey was voluntary and that they would not be jeopardized in their participation. Permission was sought from both students and laboratory facilitators before undertaking this research. The laboratory capacity is roughly 25 students per laboratory session, hence 4 different groups of students formed part of this research cohort. The survey took about 15 minutes to complete.

4.2. Instrument and procedure

A modified (adapted for inclusion of other questions) survey, which was developed by Deacon & Hajek (2011), was used for this study. The survey has 13 questions, with a 5-point Likert response scale, ranging from "Strongly disagree" to "Strongly agree". Results are expressed as a percentage. For discussion purposes, the "Strongly Agree" and "Agree" percentages are combined. To obtain a positive perception about the value of laboratory practicals, items in the percentage range of 80% and above were considered. Items of the questionnaire are also clustered into one of the five goals of the conceptual framework mentioned above. This questionnaire has questions that pertain to the nature of the student's experiences in the laboratory. Over and above these questions, five open questions were incorporated to give a holistic picture of the laboratory offering at the University of Johannesburg. These questions are aimed at including points not mentioned in the table to improve the value of practical work. The nature of these five questions are given below (also taken from the above reference (Deacon & Hajek, 2011)):

1. What did you like about the labs?
2. What did you dislike about the labs?
3. Please provide your suggestions for changes or improvement in the lab sessions.
4. The lab component of the course should be worth... of the overall course mark
 - a. Less than 20%
 - b. Equal to 20%
 - c. Greater than 20%
5. Prior for the lab session, I prepared for each lab session by doing the following:
 - a. Reading the lab manual
 - b. Reading my notes and/or textbook
 - c. Asking my friend about the lab experiment
 - d. I did not prepare for the lab session

5. RESULTS

The results of the survey are given in the table below (For purposes of discussion Strongly Agree/Agree and with Strongly Disagree/Disagree are combined).

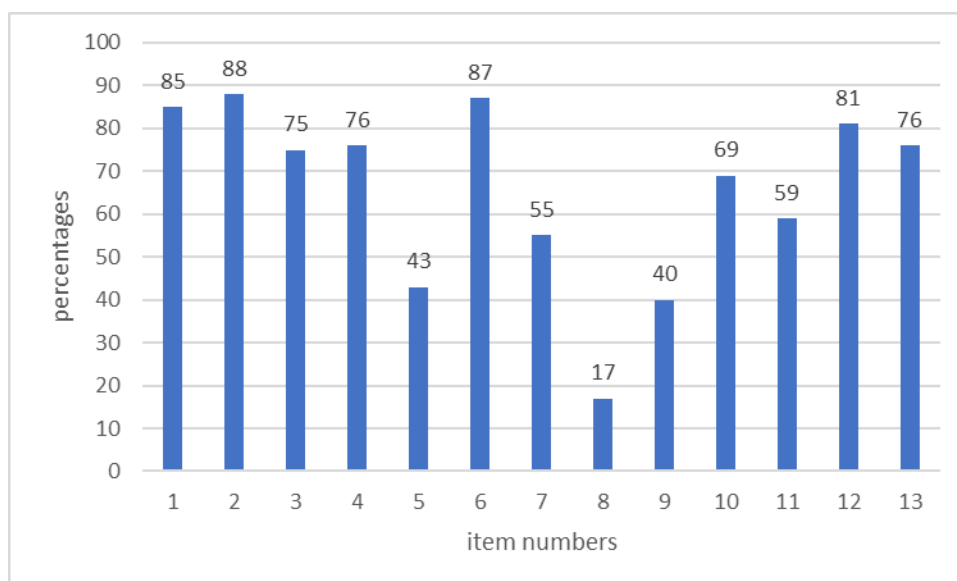
5.1. Perceptions of the students' value of their laboratory experiences

Table 1.
Factors contributing to the students' perceptions of the value of the laboratory offering.
Results are presented as a percentage.

No	Description	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	The labs contributed to my knowledge and understanding of physics	45	40	10	0	5
2	The labs helped to improve my lab skills and techniques	48	40	8	4	0
3	I see the relevance of the experiment in my physics studies	35	40	12	6	7
4	The labs were interesting	44	32	15	6	3
5	I recommend the lab component should include a pre-lab quiz	15	28	32	13	12
6	Adequate help was provided during the lab session	60	27	13	0	0
7	The deadline for the submission of lab reports should be extended	18	12	25	35	10
8	The time allocated for the experiment should be extended	5	12	28	42	13
9	I receive constructive feedback on my lab report	4	36	34	13	13
10	I was marked fairly on my lab report	6	63	7	17	7
11	The experiment helped me connect with the theory done in class	17	42	14	13	14
12	The experiment was interesting and enjoyable	43	38	9	8	2
13	This experiment helped me develop my data interpretation skills	28	48	16	8	0

The figure below is a graphical representation of the combined percentages for each of the items in table 1 under the “Strongly Agree” and “Agree” columns.

Figure 1.
Combined percentages for each of the items under the columns “Strongly Agree” and “Agree” in table 1.



From figure 1, we see that a large majority of students have responded positively about the laboratories in respect to its contribution to their knowledge (item 1 - 85%) as well as to an improvement in their laboratory skills (item 2 - 88%). Most students appear to see the relevance of the practical work in their physics studies (item 3 - 75%). A huge effort was made by lecturers to make the laboratory sessions interesting (item 4 - 76%) and the experiments interesting and enjoyable (item 12 - 81%). Students have seen the importance of the practicals (in the laboratory) in relation to the theory covered in class (item 11 - 59%). In respect to the assistance provided to students during laboratory sessions, (item 6 - 87%) students are in overwhelming agreement. Less than 50% of the students are of the opinion that pre-lab quiz should be introduced to improve their preparedness for laboratory sessions (item 5 - 43%). The time allocation for experimental investigation were more than adequate and thus no need for extension (item 8 - 17%). Item 7 (55%) for which the students have responded negatively pertains to the time-lines for the submission of laboratory reports. They have indicated that the time for the submission of such reports were more than adequate. This is strategically done by us to get the students to do practicals on a weekly basis. Another factor for which the students have responded positively was the aspect of laboratory reports being fairly assessed (item 10 - 69%), but they were unhappy about the feedback they received in such reports. They felt that the feedback was not constructive enough in understanding their mistakes (item 9 - 40%). One must bear in mind a software system was designed to mark these reports hence a timeous return of reports to students. Reports only gives them marks for correct data capturing, accuracy of data, analysis of the data and a conclusion. Lecturers then do a post mortem of

the practical work, identifying high frequency errors and mistakes to be avoided in subsequent practicals. In the final item of the questionnaire (item 13 - 76%), the students were very positive about the experiments as it provided them with an opportunity to improve their data analysis skills and interpretation skills.

5.2. Students' responses to the open questionnaire

Students "likes" about the laboratories were overwhelmingly positive, without a single negative comment. Samples of such responses are as follows:

- Better understanding of what I have been doing in class
- They helped me connect with the theory in class
- Fun to do the experiments
- So much equipment available to us
- Expansion of knowledge
- Help us get practical knowledge
- Labs are open and spacious
- Enjoyable practical experience
- It is easy to understand better in the labs
- Everything is well organized.
- They are safe
- A variety of experiments available

The "likes" reflects in some of their comments one of the aims of practical work, namely a correlation between the theories covered in class and the experiments done in the laboratory. The fact that the students enjoy their practical work and have fun in doing their experiments reflects a positive perception of the value of practical work and this indicates to us that effective learning is taking place in the laboratory. Further, students also show an appreciation for the physical aspects of the laboratory, namely the safety features of the laboratory, the infrastructure and learning space.

On the other hand, student's comments on the aspect of "dislikes" of the laboratories were very few, and samples of their comments are as follows:

- Old resources
- Equipment malfunction (at times)
- Time of day for practicals
- We do not do practicals according to the theory
- Some experiments are too long
- Labs are too cold
- Slightly complicated at times
- Working by myself

Most of our laboratories are used throughout the day without a break between periods and thus it is difficult for us to assign all laboratory sessions in the morning. At times some of our equipment in the laboratory break, which arises from frequent use of them and thus they will have to be repaired at a later stage. Students are not aware that before any practical session, all equipments are in good working order, thanks to a standby technician. Some students complain that the experiments are too long and this stems from the fact that they could be doing a temperature related experiment and for them to take any readings they will have to wait for equilibrium conditions to establish itself. A dislike about the laboratories being too "cold" is an understatement because they fail to say that it is well ventilated a requirement for the running of our laboratories.

In terms to the weighting of the practicals in relation to the theory, 60% of the students have suggested that the weighting of the practical should be no more than 20%. Likewise, 60% of the students have indicated that they have prepared for each laboratory session prior to the practical session (thus the students have shown a keen interest in their practical work and appreciate its value).

6. DISCUSSION AND CONCLUSION

This research was done to get some feedback from students about their perceptions about the value of the nature of undergraduate practical offerings and factors that contributes to their positive perceptions of the laboratories. It was found that of the many items in the questionnaire, many factors contributed to a positive perception to the value of their laboratory experiences. The item that contributed most to the satisfaction of the students was item 1 and that pertains to conceptual understanding and this factor contributed to a better understanding of physics. This item aligns itself well with goal 3 of the conceptual framework for this study. Other factors of the laboratory offering, such as those pertaining to the help that the laboratories provided in developing their analytical (item 2) and interpretation skills (item 13), were well received. This is essential in their reports that they must submit their reports which is streamlined (software compliant) and requires them in some instances to provide equations, using an excel program for data analysis. This factor aligns itself well with goal 2, which deals with experimental and analytical skills in successful completion of their laboratory reports. Of paramount importance of the laboratory offering is to make laboratory sessions engaging, interesting and enjoyable (items 2, 4 and 12). This will ensure that the students are engaged in their practical work for a sustained period whilst gaining some expertise in the Art of Experimentation (goal 1). Such engagement in experimental procedures will result in significant laboratory experience and thus leading them to appreciate the value of practical work. They have alluded to these perceptions about the laboratory in the open questions that were asked, where they have indicated that the labs were fun, it improved their understanding and that it was an enjoyable experience. This may imply that effective learning is taking place in the laboratory (Emson, 2013). Goal 1 may suffer some setbacks in that it is specifically designed (cubicles layout with a technological flair) and that it does not allow students to design their own experiments. For the understanding of the Basic Knowledge of Physics (goal 4), factors such as items 11 and 3 have contributed to a better understanding of physics and further the students were able to find a better relationship between the theory covered in class to the practicals done in the laboratories. According to Wilcox and Lewandowski (2017), the foundations of physics are built on the interplay between theory and experiment. Thus, the theory helps to provide meaningful directions to experimental results. This goal refers to the connections they make with respect to the theory as well as to its relevance in their field of study. On the issue of Collaborative Learning skills (goal 5), this goal has not been achieved in our laboratory since the laboratories were designed for students to work in cubicles to conduct their own experiments but suffice to say that we have seen them work collaboratively outside the laboratory in sharing their ideas about the practical work.

Further, other factors for which students have responded negatively pertain to their feedback to laboratory reports. According to Dunnett, Gorman, and Bartlett (2019), robust and frequent feedback to practical assessments are crucial for students in understanding their mistakes. Our students do receive frequent feedback, but they do not seem to understand the comments provided. This happens because they are not acquainted with the

software that is used to assess their practicals. Besides this aspect, largely their laboratory experiences were largely positive on many items of the questionnaire and this contributed to a better understanding of their physics.

In summary, four factors had a positive influence on the students' perceptions about the value of the physics laboratory. They ranged from the labs contributing to their knowledge and understanding of physics, the labs providing them with an opportunity to improve their lab and technical skills, the labs provided them with adequate help during lab session and to the labs making physics interesting and enjoyable. These factors tie in well with the goals set out by the AAPT (1998) in the conceptual framework for undergraduate physics laboratories.

REFERENCES

- AAPT (American Association of Physics Teachers). (1998). The goal of introductory physics laboratory. *American Journal of Physics*, 66(6), 483-485.
- Deacon, C, & Hajek, A. (2011). Student Perceptions of the Value of Physics laboratories. *International Journal of Science Education*, 33(7), 943-977.
- Dunnett, K., Gorman, M.N., & Bartlett, P. A. (2019). Assessing first year undergraduate physics students' laboratory practices: seeking to encourage research behaviours, *European Journal of Physics*, 40(1), 015702.
- Elawady, Y. H., & Tolba, A. S. (2009). Educational Objectives of Different Laboratory types: A Comparative Study. *International Journal of Computer Science and Information Security*, 6(2), 89-96.
- Emson, W. (2013). Tertiary Students' Perceived Value of Practical Work as Contributing to the Learning of Science (Master thesis, School of Education, University of Auckland, New Zealand). Retrieved from <http://aut.researchgateway.ac.nz/handle/10292/5315>
- Fraser, B. J., McRobbie, C. J. & Giddings, G. J. (1993). Development and cross-national validation of a laboratory classroom environment instrument for senior high school science, *Science Education*, 77(1), 1-24.
- Freedman, M. P. (2002). The influence of laboratory instruction on science achievement and attitude towards science across gender differences. *Journal of Women and Minorities in Science and Engineering*, 8(2), 191-200.
- Hanif, M., Sneddon, P.H., Al-Ahmadi, F.M., & Reid, N. (2009). The perceptions, views and opinions of university students about physics learning during undergraduate laboratory work, *European Journal of Physics*, 30(1), 85-96.
- Hu, D., Zwickl, B.M., Wilcox, B.R., & Lewandowski, H.J. (2017). Qualitative investigation of students' views about experimental physics, *Physical Review Physics Education Research*, 13(2), 020134-1 – 020134-12.
- Kirschner, P. A., & Meester, M. A. M. (1988). The laboratory in higher science education: Problems, premises and objectives. *Higher Education*, 17(1), 81-98.
- Luketic, C. D., & Dolan, E. L. (2013). Factors influencing student perceptions of high-school science laboratory environments. *Learning Environment Research*, 16(1), 37-41.
- Pekmez, E.S., Johnson, P., & Gott, R. (2005). Teachers' understanding of the nature and purpose of practical work, *Research in Science & Technological Education*, 23(1), 3-23.
- Ramma, Y., Bholoa, A., Watts, M., & Nadal, P.S. (2018). Teaching and learning physics using technology: Making a case for affective domain, *Journal of Educational Inquiry*, 9(2), 210-236.
- Shah, I., Riffat, Q. & Reid, N. (2007). Students' perception of laboratory work in chemistry at school and college in Pakistan, *Journal of Science Education*, 8(2), 75 – 79.
- von Aufschnaiter, C., & von Aufschnaiter, S. (2007). University students' activities, thinking and learning during laboratory work. *European Journal of Physics*, 28(3), 51-60.
- Wilcox, B.R., & Lewandowski, H.J. (2017). Students' views about the nature of experimental physics, *Physical Review Physics Education Research*, 13(2), 020110-1 020110-10.

AUTHOR INFORMATION

Full Name: Prof, Leelakrishna Reddy

Institutional affiliation: Prof, University of Johannesburg

Institutional Address: 37 Nind Street, Doornfontein, Gauteng, Johannesburg, South Africa.

Short biographical sketch: I am a senior lecturer at the University of Johannesburg in the Department of Applied Physics. My area of specialty is Science Education, Condensed Matter and Nanotechnology.