# GENDER DIFFERENCES IN ATTITUDE TO LABORATORY EXPERIENCES OF LABORATORY TEACHING OF PHYSICAL SCIENCE AT A SOUTH AFRICAN UNIVERSITY

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**ABSTRACT**

A well-resourced laboratory well laden with the latest equipment provides a fertile environment for constructive experimentation. Such laboratories can deliver constructive laboratory programmes provided it adheres to the fundamental goals for laboratory teaching. Enshrined in these goals are factors such as: the art of experimentation, experimental and analytical skills, conceptual learning, understanding the basis of knowledge in physics and the development of collaborative learning skills. For this study, we intends to investigate the attitude and experiences of students towards laboratory teaching at a university. In particular, the attitude of males are compared to that of females with the goal of finding if the laboratory teachings are making a valuable contribution to the understanding of physics at a fundamental level.

A modified questionnaire of Sneddon & Douglas (2013) has been used as a tool to measure the students' perceptions of their attitude and experiences of laboratory work at a South African university. We have administered these questionnaires to 192 1st year university students undertaking multi-disciplinary studies with physics as a pre-requisite for their studies. Concomitant to this study, a longitudinal study was done to compare performances of students, both males and females, to laboratory work.

The results of this study indicate that students, both males and females, finds their laboratory work useful, understandable and interesting. This helps them to understand the theoretical part of physics better. From this study it is concluded that there is a marginal difference in the attitude and experience of both males and females towards practical work at a university level.

**Key words:** Well-resourced laboratory, laboratory teaching, attitude and laboratory experiences

## 1. Introduction

Laboratory practicals can be regarded as an indispensable tool in the teaching and learning of physics (Hanif et al., 2009; Sneddon & Douglas, 2013). In most cases laboratory practicals takes the form of teacher-led demonstrations, followed by practical work carried out by the students themselves. Hodson (1996) is of the opinion that when science practicals are taught, they should conform to 3 broad goals, namely, science should:

- Help students to learn science
- Help students to learn about science, and
- Enable students to do science.

On the other hand, the Institute of Physics (2009) have outlined the broad principles that teaching of science practicals should entail (Sneddon et al., 2009):

They should give students an opportunity to

- Plan and execute an experiment
- Use equipment to acquire data

- Analyse the acquired data through some technique
- Interpret uncertainties in the measurement, and
- Give support for the results of the experimentation.

Given such opportunities in the laboratory, it should provide students with rich experiences of laboratory learning. So what does experiences in the laboratory entail? A laboratory is a place where students are busy illustrating, demonstrating and verifying laws and concepts in science (Hofstein & Lunetta, 1982; Campbell & Bohn, 2008) for the development of a wide range of illusive scientific skills (Hanif et al., 2009). Such skills are only attainable by students at a senior school level or by students engaged with undergraduate degree courses in science (Reid & Serumola, 2006, 2007). It is suggested by (Hanif et al., 2009) that laboratory experiences can play a paramount role in the development of such skills.

This research aims to compare the attitude of both male and female students to their perceived laboratory experiences in the laboratory. The reason for undertaking such a research is to shed light on the role of gender in science with respect to laboratory experiences. We are informed by research that the uptake of female students for physics subjects compare to male students is disturbingly low (IOP Institute of Physics, 2012). Other research have alluded to significant differences of both male and female students to practical work (Trivedi & Sharma, 2013). It has been reported by other researchers (Osborne et al.,
2003) that the ratio of male students to female students to the uptake of physics is 3.4:1. However, once female students pursue a physics disciplined at a university, their attitude to laboratory experiences is quite the opposite, in that there is a marginal difference in their attitude to laboratory experiences in the laboratory (Sneddon et al., 2009). This research seeks to explore the attitude and views of both male and female students to laboratory experiences in the laboratory. Such experiences are measured through an agreed set of goals for laboratory teaching.

## 2. Research Question

This study is underpinned by the following research question:

What are the differences in attitude to laboratory experiences between undergraduate male and female students when performing physics practicals?

## 3. Theoretical Framework

The theoretical framework for this study is underpinned by 5 goals mentioned in the paper of the American Association of Physics Teachers (AAPT, 1997) for laboratory physics teaching, and they are:

### 3.1 The Art of Experimentation

Laboratory sessions should effectively engage students with significant experiences and experimental processes.

### 3.2. Experimental and Analytical skills

Laboratory sessions should assist students to develop a broad array of experimental skills in experimental physics. Such skills should be able to help them to be able to analyse data collected from the experimental processes.

### 3.3. Conceptual Learning

The experimental work done in the laboratory should help students to master the basic concepts in physics.

### 3.4. Understanding the basis of knowledge in physics

The undisputable role of direct observation in the laboratory should help students to have a better understanding of the theory covered in class. They should be able to make deductions based on the outcomes from the practical work done in class.

### 3.5 Developing collaborative learning skills

Laboratory practicals should help students to develop collaborative learning skills that could be vital in their lifelong learning endeavours.

## 4. Methods

### 4.1 Participants

A sample consisting of 192 first year university physics students, comprising of 91 female and 101 male students participated in this study. The students chosen for this study came from various faculties within the university and the purpose of this was to get a better idea of their attitudes to physics practicals.

### 4.2 Instrument and Procedure

The study made use of modified questionnaires developed by Sneddon and Douglas (2013) of the University of Glasgow in the United Kingdom. Permission was also sought from these authors as well as the lecturers to conduct this research. The questionnaire is an existing validated instrument, which addresses the issue of validity and reliability of the data collected.

The study made use of 3 questionnaires; the first questionnaire, labelled A, sought the opinions of both male and female students about their laboratory experiences in the subject. Students had to respond to a 6 item questionnaire by indicating their experiences in the laboratory. Responses were in the format of 3 categories: positive, neutral or negative. The results were presented in the form of a percentage (%). The second questionnaire, labelled B, measured the laboratory skills that the students acquired when performing experiments during their laboratory work. This questionnaire consisted of 8 questions. The response format for this questionnaire was similar to that of questionnaire A. In the final questionnaire, labelled C, which comprised of 16 questions, had a 5-point frequency response was used to measure the students' experiences in the laboratory during practical sessions.Further, a longitudinal 3-year study was also undertaken to gauge the performances of male and female students to practical work and from this, we could infer their attitude towards physics practicals. In this respect, the performances of 1155 students, comprising of 718 male and 437 female student performances were compared. The purpose of this study, in conjunction with the main study, was to compare the performances of these students to practical work.

## 5. Results

The results of each questionnaire (A, B, and C), according gender are discussed below.

**Table 1** (Questionnaire A): Opinions about laboratory experiences in the subject (expressed as a %)

| Number | Descriptor | Male | | | Female | | |
|---|---|---|---|---|---|---|---|
| | | Positive | Neutral | Negative | Positive | Neutral | Negative |
| 1 | Useful | 80 | 17 | 2 | 73 | 26 | 11 |
| 2 | Understandable | 77 | 22 | 1 | 71 | 27 | 1 |
| 3 | Satisfying | 51 | 45 | 4 | 56 | 41 | 3 |
| 4 | Enjoyable | 71 | 28 | 1 | 71 | 24 | 4 |
| 5 | Best part of subject | 49 | 46 | 6 | 45 | 49 | 5 |
| 6 | Interesting | 82 | 16 | 2 | 84 | 14 | 2 |

Students believe that their laboratory experiences in the subject were highly positive from their responses to 4 out 6 items of the questionnaire. Both male and female students share common experiences of their experiences in the laboratory. In this respect, they consider their laboratory work useful (80% for the males and 73% for the females), interesting (82% for the males and 84% for the females), understandable (77% for the males and 71% for the females) and enjoyable (71% for the males and 71% for the females). For the remaining items of the questionnaire, their responses were less positive. At the other end of the spectrum, their negative responses were too small to be significant.

**Table 2** (Questionnaire B): The skills that you learnt and what did the experiments teach you (expressed as a %)

| Number | Descriptor | Male | | | Female | | |
|---|---|---|---|---|---|---|---|
| | | Positive | Neutral | Negative | Positive | Neutral | Negative |
| 1 | Time management | 71 | 25 | 4 | 73 | 24 | 3 |
| 2 | Communication | 50 | 39 | 12 | 63 | 32 | 5 |
| 3 | Report writing | 60 | 30 | 10 | 59 | 34 | 7 |
| 4 | Patience | 67 | 28 | 5 | 66 | 30 | 4 |
| 5 | How to use equipment | 81 | 19 | 0 | 82 | 16 | 1 |
| 6 | Physics is fun | 67 | 33 | 1 | 63 | 32 | 5 |
| 7 | Link to theory | 66 | 28 | 6 | 54 | 35 | 11 |
| 8 | Verification of the laws of physics | 78 | 21 | 1 | 78 | 19 | 3 |

Results from the 2nd questionnaire resonate a similar comparison of gender description of skills acquired and lessons learnt from their laboratory experiences. A large majority of students, both males (81%) and female students (82%) have a pretty good idea of how to usethe equipment in the laboratory for the conductance of practical work. An overwhelmingly large percentage of students were in agreement that their laboratory experiences could be seen as one of verification of the known laws in physics. However, a further 73% of the female and 71% of the male students, have indicated that they learnt how to use their time effectively in the laboratory. A relatively large number of male (67%) and female (66%) students have responded positively on the aspect of being patient in the laboratory during practical work. It might appear to the male (50%) students that the structure of the laboratories at this university could offer less opportunities for communication with fellow peers compared to the female (63%) students. On a more positive note, responses to the statement “Physics is fun” has been encouraging (67% for the males and 63% for the females).

**Table 3** (Questionnaire C): Students’ experiences of the laboratory work (expressed as a %). In the table SD, D, N, A and SA are taken to represent Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree, respectively. For simplicity, SD and D and SA and A were combined and represented as broadly Disagree and Agree, respectively.

| No | Descriptors | Male | | | Female | | |
|---|---|---|---|---|---|---|---|
| | | D | N | A | D | N | A |
| 1 | I prefer the written instruction for experiments | 25 | 20 | 55 | 15 | 30 | 55 |
| 2 | Laboratory work helps me get a better understanding of the coursework | 6 | 17 | 77 | 3 | 20 | 77 |
| 3 | Laboratory physics enhances my understanding of physics | 4 | 10 | 86 | 3 | 16 | 79 |
| 4 | I feel confident to conduct the | 4 | 11 | 86 | 6 | 21 | 73 |
| 5 | The experiment procedure is clearly explained in the instruction manual | 4 | 14 | 82 | 2 | 18 | 80 |
| 6 | I feel confused because I am following a procedure without fully understanding the physics behind t | 42 | 16 | 42 | 39 | 22 | 39 |
| 7 | There appears to be a good link between the theory done in class and the | 14 | 24 | 62 | 20 | 31 | 49 |
| 8 | I am unsure of what is expected of me when I do the write up | 43 | 25 | 32 | 42 | 41 | 17 |
| 9 | I only understand the experiment once I | 40 | 26 | 34 | 45 | 24 | 31 |
| 10 | The time allocated for each experiment is sufficient | 14 | 15 | 66 | 6 | 11 | 83 |
| 11 | The teachers provides us with valuable assistance with our work | 7 | 6 | 87 | 4 | 5 | 91 |
| 12 | Pre-laboratory discussions were very helpful to proceed | 5 | 4 | 81 | 7 | 15 | 78 |
| 13 | Reading the manual before the practical has helped me a great deal | 6 | 20 | 74 | 10 | 16 | 74 |
| 14 | This is the first time I am really enjoying my experimental work | 18 | 10 | 62 | 9 | 26 | 65 |
| 15 | I feel like a real scientist working in the laboratory | 11 | 17 | 72 | 8 | 17 | 75 |
| 16 | Physics experiments are fun because I can work with my friends | 11 | 22 | 67 | 10 | 22 | 68 |

An overall impression of questionnaire C is that the responses from both male and female students tend to favour the option “Agree” and “Strongly Agree” to most of the items. For both male (87%) and female (91%) students, item 11, which describes the role of the teacher in the practical work, is considered the most important aspect of the practical offerings. The experimental procedures discussed at the onset of practical work was fundamentally crucial for both male (82%) and female (80%) students in effective execution of their practical work. This item correlates well with item 12, the usefulness of pre-laboratory discussions. As a precursor to proper understanding of laboratory work, prior reading of the laboratory manual was a must. Their responses to this item is encouraging (74% for the females and 74% for the male students). Male students are in agreement that laboratory work helps them to have a better understanding of theory done in class (item 2, 77%) and the effect of this is an enhancement of their understanding of physics (item 3, 86%). There appears to be a marginal difference of similar items with respect to the views of female students (77% and 79%, respectively). However, the confidence of male students (86%) to conduct the experiments compared to the female (73%) is a slight concern. A fair majority of students (55% for the female and 55% for the male students) prefer written instructions for practical investigations instead of verbal instructions. The glamour of working as scientist in the

laboratory is evident from their positive responses to this item in the questionnaire (75% for the females and 72% for the male).

**Results of the open question**: The question we asked at the end of questionnaire 3 was: My experiences in the laboratory are really great because:

For this question, majority of the male and female students have indicated that physics is fun, enjoyable and interesting. They felt that their confidence in practical work was high when they conducted the experiments by themselves. Some specific comments from students, differentiated according to gender are:

Male students

- I get to understand what I have been taught in high school and now I can connect the dots and understand it more than just reading the theory.
- I get to use a hands-on approach in the field of physics.
- The experimental procedures are fully explained and this builds my confidence and helps me to perform better.

Female students

- I learn how to use and handle physics equipment. I can work with a group, sharing opinions on how to approach a particular experiment.
- I get to understand more about the theory I did not understand in class.
- The experiments are amazing and doing them on my own gives me a better idea of understanding the work done in class.

Table below depicts the overall performance in practical work over a 3-year period which informs the context of this study, which primarily focusses on attitudes in terms of gender differences. The selected sample of students served to ensure achievement of a cross- sectional picture in relation to attitudes across various faculties within the university. The modules reflected in the table below forms part of the department's service offering to other faculties. This provides us with an opportunity to assess the quality of the service that we provide to other faculties within the university.

**Table 4**: Table 4 reflects such performances between the four groups of students over a period of 3 years.

| Module | Year | Number of students | | Average performance (%) | |
|---|---|---|---|---|---|
| | | Male | Female | Male | Female |
| PHY1BEEP (Electrical Engineering) | 2014 | 109 | 29 | 68 | 71 |
| | 2015 | 120 | 33 | 75 | 77 |
| | 2016 | 125 | 38 | 69 | 72 |
| PHY1ADP (Biomedical Technology) | 2014 | 16 | 36 | 71 | 75 |
| | 2015 | 14 | 25 | 84 | 86 |
| | 2016 | 11 | 31 | 69 | 65 |
| | 2014 | 69 | 38 | 63 | 71 |

| | | | | | |
|---|---|---|---|---|---|
| PHY1YKP (Building And Construction | 2015 | 75 | 33 | 65 | 71 |
| | 2016 | 86 | 54 | 62 | 68 |
| PHY1YFP (Homeopathy and Chiropractic) | 2014 | 16 | 53 | 86 | 72 |
| | 2015 | 56 | 14 | 70 | 67 |
| | 2016 | 21 | 53 | 63 | 65 |

From this results, we see that firstly the number of male (718) students taking physics practicals exceeds that of the females (437) and secondly, that there is a marginal differences in performances between the male (70.4%) and female (71.6%) students to practical work.

**6. Discussion**

The overall results from both genders were generally positive about their laboratory experiences. In this respect, students' opinion about their laboratory experiences were found to be interesting, enjoyable and useful. On the aspect of skills acquired from their laboratory work, 2 items from the questionnaire featured more strongly than other items and they were time management and how to optimise the use of equipment in the laboratory. Verification of the laws of physics has been considered by majority of the students as the main objective of the practical investigations.

A well developed and understandable laboratory manual with clearly outlined procedures and processes to be followed (items 1, 5 and 13) as well as a time line for experimental execution (item 10) has been considered a huge plus for the department. These responses by students are consistent with part of goal 1 (AAPT, 1997) that emphasises the engagement of students with experimental processes. However, the aspect of designing investigations appears to be a grey area in our practical offerings, in that our focus is on teacher-led demonstrations, where students were aiming to verify laws and concepts that were covered in the theoretical part of physics. It is unlikely for new discoveries to be achieved through these processes but more likely achieved through inquiry-based investigations (Hanif et al., 2009). The role of the teacher in facilitating laboratory discussions (item 12) and the valuable assistance played by them (item 11) when students are engaged with practical work are also closely aligned with the first part of goal 1, the Art of Experimentation (AAPT, 1997). A typical laboratory should help students to develop a broad array of both experimental and analytical skills so that they have confidence (item 4) to perform their practical work and at the same time have the necessary skills to analyse the data analytically when the write-up is done. Whilst they may be enthusiastic to carry out an experimental procedure, they however, lack understanding of the physics behind each experiment (item 6) and also lack the necessary analytical problem solving skills for data analysis (items 8 and 9). Thus goal 2 made by AAPT (1997) is only partially achieved by both male and female students.

Students (both males and females) have overwhelmingly agreed that laboratory work has helped them to understand the theory covered in class and the subsequent effect of this is an enhancement of their understanding of physics (items 2 and 3) at a fundamental level. Both groups of students have indicated that they really enjoyed their laboratory work (item 14). These responses are consistent with goal 3 (AAPT, 1997) that pertains to conceptual understanding of physics.

The response of students to item 7 appears to be more favourable to male students than female students. This item refers to the linkage of the theory done in class to the practicals covered during practical sessions. The only goal to associate this item is goal 4 (AAPT, 1997), which refers to the understanding of the Basis of Knowledge in Physics. This goal is also partially achieved. The attention given to the quality of collaborative learning, ties in well with goal 5 (AAPT, 1997), where students seem to have fun while performing experimental work together.

From the longitudinal study, there appears to be a marginal difference in the overall assessment marks of both males (70.4%) and females (71.6%) to physics practicals and this is consistent with the marginal difference in attitude towards the practicals.

## 6. Conclusion

The study considered the attitude of students to laboratory experiences of physics practicals. Gender experiences of laboratory practicals and its benefits were counter-checked against the goals set out by AAPT (1997) for laboratory teaching. Most of the goals were found to be partially or fully achieved. In goal 4, there appeared to be some disparity in the perception of the views between the male and female students of the linkage between the theory done in class and its associated practicals covered in the laboratory. Solomon (1999) makes a strong argument about practical and theoretical learning supporting each other, in that students will be able to make connections of what they observed to what is learnt in theory (Jokiranta, 2014). Students in general have found their laboratory experiences to be fun, interesting and useful.

These positive views were further emphasized in their responses to the open-ended question about their laboratory experiences. Students were highly appreciative of the role of the teacher in the assistance they provided in making their practical work manageable. They have also found the pre-laboratory discussions to be beneficial in enabling them to perform the experiments. This concurs with the research done by Johnstone et al. (1998), where it was found that pre-laboratory discussions were used to foster a positive attitude in terms of shared knowledge. Working together in a collaborative way has proved to have an enhanced effect on the efficacious way of their learning. From a 3-year longitudinal study, it was found that more males prefer physics than females but that the performances (assessments of the practicals) to practical work between the genders is only marginal. Further, it is also concluded from this anecdotal research that there is no significant differences in attitude to their laboratory experiences between the male and female students and that laboratory teaching is meeting its mandatory goals.

## REFERENCES


American Association of Physics (AAPT). (1997). Goals of the introductory physics laboratory. *Physics Teacher*, 35, 546-548.

Campbell, T., & Bohn, C. (2008). Science laboratory Experiences of High School Students Across One state in the U.S.: Descriptive Research from the Classroom. *Science Educator*, 17, 36-48.

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, 85-96.

Hodson, D. (1996). Practical work in school science: exploring some directions for change. *International Journal* of Science Education, 18, 155-160.

Hofstein, A., & Lunetta, V. (1982). The role of the laboratory in science teaching: Neglected aspects of research. Review of Educational Research, 52(2), 201-217.

Institute of Physics, Degree accreditation- The Physics Degree, (2009). http://www.iop.org/activity/policy/Degree_Accreditation.

Johnstone, A. H., Watt, A., & Zaman, T. (1998). The students' attitude and cognition change to a physics laboratory. *Physics Education*, 33, 9-22.

Jokiranta, K. (2014). The effectiveness of Practical Work in Science Education (Bachelor's Thesis), University of Jyvaskyla, Department of Educational Sciences.

Osborne, J. Simon, S., & Collins, S. (2010). Attitudes towards science: A review of the literature and its implications. *International journal of Science Education*, 25, 1049-1079.

Reid, N., & Serumola, L. (2006). Getting started in pedagogical Research in the physical sciences practice guide (1st edition 2003) (Hull: Higher Education Academy).

Reid, N., & Serumola, L. (2007). Scientific enquiry: the nature and place of experimentation some recent evidence. *Journal of Science Education*, 7, 88-94.
Sneddon, P. H., & Douglas, R. (2013). The Attitudes Towards, and Experiences of, Laboratory Teaching in Year 1 Chemistry and Physics University Courses. *The Higher Education Academy*, 9, 49-54.
Sneddon, P.H., Slaughter, K. A., & Reid, N. (2009). Perceptions, views, and opinions of university students about physics learning during practical work at school. *European Journal of Physics*, 30, 1119-1129.
Solomon, J. (1999). Envisionment in practical work: Helping pupils to imagine concepts while carrying out experiments. *Practical work in Science Research – Recent Research Studies*, Frederiksberg: Roskilde University Press, 60-74.
Trivedi, R., & Sharma, M. P. (2013). A study of Students' Attitude towards Physics Practical at Senior Secondary Level. International Journal of Scientific & Research Publications, 3, 1-4.