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Article *in* International Journal of Learner Diversity and Identities · January 2013

DOI: 10.18848/2327-0128/CGP/v19i03/48542

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Do Gender Differentials Play Any Role in University Physics Students' Performance?[1]

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Abstract: Against international literature that indicates that gender differences exist in the performance in introductory physics level students, this paper has examined the prospects of gender based differences in students' performance in introductory physics at the university level in South Africa. The study was conducted at four South African universities using a sample of 194 students. A third (68) of the participants in this research were female students. Student performance was measured through two instruments, namely 1) The Force and Motion Conceptual Evaluation (FMCE) tests adapted from Thornton and Sokoloff (1998) and 2) the student's introductory physics mechanics marks. Both FMCE and mechanics courses lay the foundation for other physics courses. Student performances on the two instruments were analysed. The students' outcomes on these tests suggest that in the South African context, gender differentials do not necessarily predict performance in physics. In conclusion, this paper discusses other factors which in the context of South Africa need attention as possible barriers to general outcomes in physics.

Keywords: Gender, Physics, Performance, University

Introduction: The Challenge of Science and Techonology Skills in South Africa

Two main pieces of the apartheid education legislation which are the Bantu Education Act (47 of 1953) and the Extension of University Education Act (45 of 1959) (South African history online 2012) resulted in the adoption of a curricular that was 'suitable' for black people and their requirements as well as put an end to black students attending historically White universities. That black people were marginalised academically even before apartheid has been proven (South African history online 2012). More drastically, apartheid laws specified the areas of knowledge and the skills acquisition that were appropriate for the blacks. Apartheid legislation also precluded blacks from studying in identified subject areas like metallurgic engineering and science and mathematics at school level. Teaching and learning methods were designed to blunt the edges of an enquiring mind by subjecting students to what is referred to as 'banking', whereby the teacher provides information and the student receives through memorization and regurgitation (Naidoo 2003 in Netswera and Mathabe 2006). Not only apartheid laws but African traditional and cultural practices too marginalised women from participating fully in academic activities as equal partners to males. Hence the current huge skills deficit of both blacks and black females in particular in the South African science sectors (Walker 1998; Mama 2006; Department of Science and Technology (DST) 2007).

The challenge for democratizing the South African academic landscape seem to be low on national priorities as the country faces a myriad of challenges that sets back Nelson Mandela's vision of expanding the economy and improving living conditions of the majority of South Africans. With a population of nearly 50 million South Africa is reported to have on average 121 000 professionals in the fields of science, engineering and technology. Attainment of the Mandela vision requires an innovative workforce which is currently in acute shortage (Armstrong 1995; DST 2007).

[1] *Paper published by the International Journal of Learner Diversity and Identities, Volume 19, 2013, www.thelearner.com, ISSN 2327-012*

Science and Technology Challenge – An International Phenomenon

Researchers like Tai and Sadler (2001) and Reis and Park (2001) have shown that there is a poor representation of females in scientific research and engineering jobs. The differences in number of males and females in physics classes at schools and universities differ From country to country. Many countries experience under-representation of females in physics education (Rolin 2008; Sharma and Bewes 2011). Mallow et al. (2010) report that in Danish gymnasia and universities as well as in US universities there is a large number of females compared to males in mathematics/science streams. At the same time Gardner cited in Reid and Skryabina (2003) indicates that "sex is probably the single most important variable related to pupils' attitudes to science" (p. 509). According to Reid and Skryabina (2003) in England and Wales, girls in physics courses and examinations at schools are under-represented at approximately 1:3 at O level. Lorenzo et al. (2006) also report that in the USA too, females are underrepresented in science and technology-related courses and careers and their average scores are lower than those of males on science tests at the secondary and tertiary levels. In their research, Tai and Sadler (2001, 1035) measured students' success by using the final course grades the students earned in their respective introductory undergraduate physics courses. Their study revealed that "female students are not performing at the same level as their similarly qualified male counterparts". Other researchers (Kortemeyer 2009; Kost-Smith et al. 2010; Kost et al. 2009) also indicate that the gender gap in introductory physics is persistent. Lorenzo et al. (2006) further report that the largest gender differences in both achievement and professional representation remains in physics. In their study Lorenzo et al. (2006), found that interactive engagement effectively reduces the gender gap in physics. However, in a study done in Lebanon, El Hassan (2001) found that girls did as well as boys in mathematics and the sciences. Frost et al. (2005) found that at A level, girls were underrepresented by factors of 1:4. The Royal Society and Institute of Physics cited in Reid and Skryabina (2003, 510) further indicates that such "under representation of girls in physics is then propagated into physics undergraduate courses (1:8), postgraduate courses (1:10) and professional activity as a physicist (1:20)". Wyer (2003) found that gender was significant for both commitment to an undergraduate science major and career and that women commitment were found to be lower than that of men. This justifies the underrepresentation of females even in postgraduate classes.

The cognitive difference model (Editorial 2005) assumes that students with aptitude in mathematics (mostly men) choose to continue in physics, while those lacking mathematical aptitude (mostly women) switch to other fields. Reid and Skryabina (2003) reported that towards the end of the second year of secondary school, there was a significant decline in girls' attitudes towards science compared to that of boys. Poor mathematical and physics aptitude among female learners has not fully been explained beyond just the negative attitude prevalent among them towards these courses. According to Robertson (2006), to overcome this problem the school system should fully engage female learners in physics classrooms to shape their attitudes positively and affect long-term interest among them. Boys and girls differ with regard to making sense of physics as presented in traditional physics classrooms (Kahle and Meece in Stadler et al. 2000). Stadler et al. (2000) however, think that girls' interests and learning outcomes can be improved by embedding the content to be learned in appropriate contexts. According to Ding and Harskamp (2006, 332), "males see themselves as the rightful and superior problem-solvers while females think physics is a masculine job". Ding and Harskamp (2006) also found that males learned much better than females within mixed-gender dyads.

Problem Statement

The history of the South African education system borrowing largely from cultural and traditional practices has been highly prejudiced not only against blacks but females in particular. In Dzama and Osborne (1999, 387) it is argued that there is conflict between science and African traditions. This conflict therefore determines the achievement of African students. Dzama and Osborne (1999, 387) also argue that "conflict between science and traditional beliefs and values is not peculiar to Africans alone" (p. 387). These authors further argue that "improvement in the performance of students succeeded rather than preceded industrial and technological development" (p. 387). The big challenge has continuously been the lack of qualified scientists and engineers to act as teachers, mentors and role models to the youth and the absence of supportive environment for serious meaningful learning of science. Dzama and Osborne (1999, 402) concluded that in a capitalist driven world students will not see a need to excel in science unless "those who work hard and succeed in learning science are economically rewarded" (p. 402).

In his speech, the Minister of Science and Technology (DST, 2007) indicated that "In South Africa women's involvement in Science, Engineering and Technology (SET) is greatest at the undergraduate level but is weakest at the crucial research level where academic knowledge is converted into products and services."

Aim of the Study

This paper explores whether female students' performance in science, specifically in introductory physics is comparable to that of their male counterparts. The study aims to answer whether or not there are gender differences in the performance of South African students in Physics.

Methodology

The design of this research is a pre-test post-test quasi-experiment research design because it does not apply randomisation principles. However it is also not a non-experimental design because multiple groups (male and females) and multiple measurement instruments [Mechanics tests (pre-test) and FMCE (post-test)] were used albeit without a control group. For this reason this research is therefore a quasi-experimental design as defined by Miller and Salkind (2002).

Research Participants

The participants in this study were 194 introductory physics students from four Historically Black Universities in South Africa. For anonymity the names of these universities cannot be revealed but will be referred to as universities 1, 2, 3 and 4. The universities referred to here as 3 and 4 have since been merged to become one new University. The research was of a convenient sampling nature and only historically black universities in the proximity of the researchers were sampled. The deans and the heads of departments under whom the physics departments reside were consulted for permission to conduct the study. Student sampling was a convenience and only students who attended first year physics classes on the dates that the survey was administered participated in the research. Students were promised anonymity and their names were not required in the survey instrument. Out of the four universities 126 (64.9%) male students and 68 (35.1%) female students participated in the survey. All the participants were black students who matriculated from rural high schools.

Instruments and Data Collection

Force and Motion Conceptual Evaluation (FMCE)

The FMCE test, like most other survey methods, is a paper and pencil test (McMillan and Schumacher 2001, 40) that "permits the collection of data from large numbers of respondents in relatively short periods and at relatively low costs" (Chadwick et al. 1984:100). The FMCE is a multiple choice 47-question standardized test which was developed to evaluate student learning in introductory physics (Thornton and Sokoloff 1998). A copy of the administered instrument was received from Sokoloff in 2004 who is one of the original test authors. The only changes/additions to the test's original version were the addition of items to source the participants' biographical details like age, gender and urban or rural origins of the students. FMCE has been used to evaluate large numbers of students at many colleges, universities, and high schools mostly in the USA (Thornton and Sokoloff 1998).

Amongst others, questions from the FMCE probed students' views of force and motion concepts "Force Sled" (questions 1-7), the "Cart on Ramp" (questions 8-10), the "Coin Toss" (questions 11-13), and the "Force Graph" (questions 14-21) (Thornton and Sokoloff, 1998). Thornton and Sokoloff (1998) found in their study that most students taught in a traditional way answered the Coin Toss questions and the Cart on Ramp questions in a non-Newtonian way.

The study of conceptual understanding using FMCE conducted mainly in the USA showed that introductory physics students do not commonly understand kinematics and dynamics concepts as a result of thorough traditional instruction (Thornton and Sokoloff 1998). Students from the Universities of Oregon and Tufts were tested on FMCE before and after Active Learning Laboratories (Thornton and Sokoloff 1998). Thornton and Sokoloff (1998) indicate that the students performed poorly before Active Learning Laboratories. In this study the FMCE is used to evaluate differences in performance among female and male students after they have completed an introductory physics course.

Mechanics Course Marks

The students' mechanics final marks were requested from the relevant departments. An average mechanics mark was made up of assignment, test, final examination mark and in some cases, practical mark. Assignments, tests and practical work contributed to the year mark or semester mark. The aggregate mechanics mark was comprised of year mark and final examination mark. Table 1 indicates the proportions of semester/ year mark and final examination mark for each university. In these universities the year/ semester mark has more weight. The tests and assignments differed from university to university in terms of content and the actual number taken.

Table 1: Average Mechanics Module Mark for Each Institution

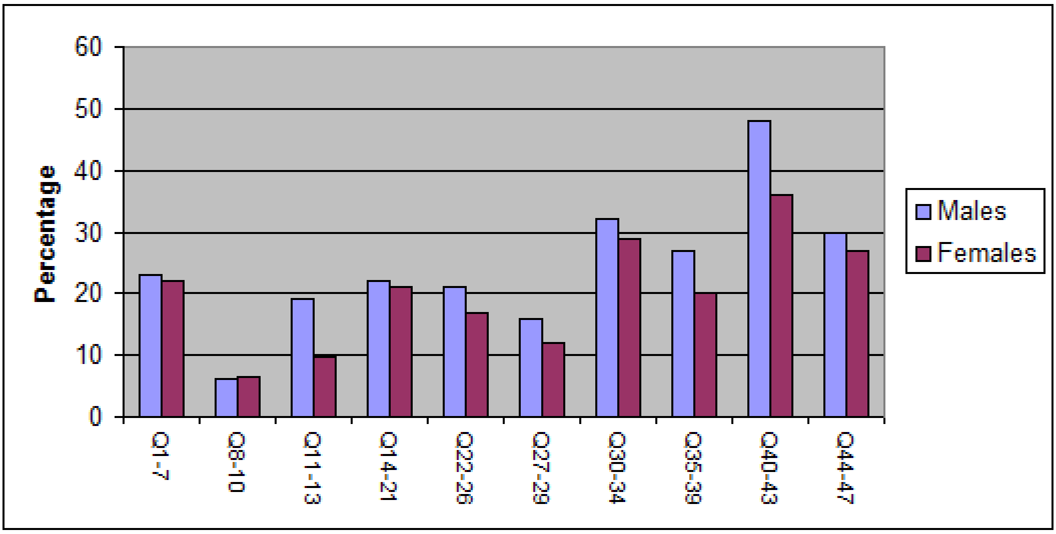
Institution	Percentage of Year/ Semester Mark	Percentage of Final Examination
1	50	50
2	60	40
3	60	40
4	60	40

Results and Discussions

In this study, female students' FMCE marks are consistently below those of their male counterparts (see Figure 1) except for questions Q8-10 ("Cart on Ramp"). Questions Q8-10 asks students about the movement of a cart on an inclined plane. Female students' performance in this group of questions is slightly above that of male students. It is also in questions Q8-10 where male and female students score the least marks. This is an indication that they all had not grasped the concept well.

Some notable differences are also evident in questions Q11-13, Q35-39, and Q40-43. The two sets of questions (Q11-13 and Q35-Q39) address falling bodies and Newton's third law respectively. These are sections that students find difficult to understand as evidenced by Thornton and Sokoloff (1998). Female students performed poorer than male students in these questions. Results show marginal knowledge gap between male and female students in questions Q40-43 and Q11-13 although Chi-Squared tests yield no significant differences. Questions Q40-43 ask students to interpret velocity-time graphs. On these questions, male students performed better than female students.

Figure 1: Students' Performance in the FMCE Questionnaire



Both female and male students performed badly in the FMCE and mechanics module with an average score below 50% (see Figure 2). All students performed better in mechanics examinations than in the FMCE test. This might be so because the FMCE is a conceptual instrument while mechanics examination mainly focused on calculation questions. These outcomes confirm the findings by Lorenzo et al. (2006) who also reported that the largest gender differences in achievement remains in physics.

Figure 2: Students' Performance in the FMCE Questionnaire and Mechanics Examination

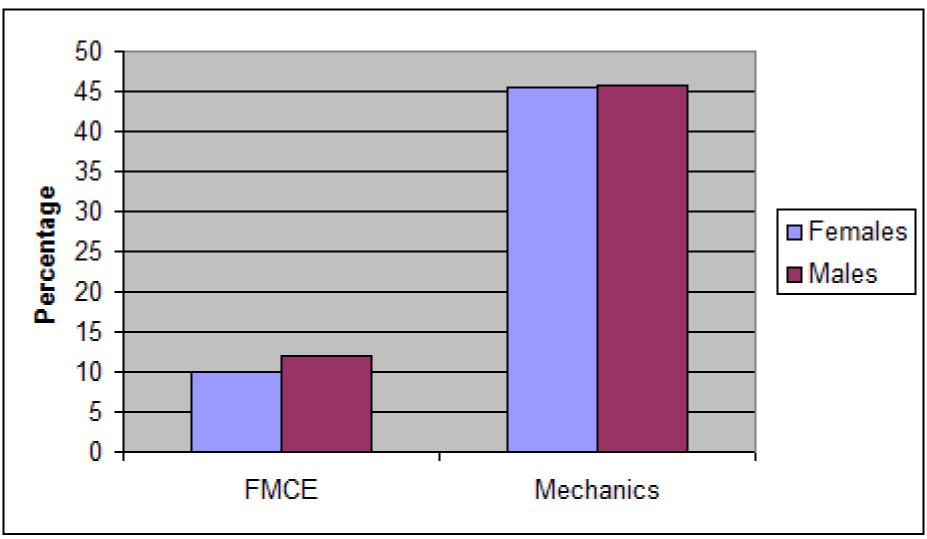


Table 2: Students' Average Percentage Marks for FMCE and Mechanics Course

	FMCE (average %)	FMCE (paired t-test, $p<0.05$)	Mechanics (average %)	Mechanics (paired t-test, $p<0.05$)

Females	9.9	0.003	45.5	0.336
Males	12.0		48.5	

Interestingly, the paired t-test values (see Table 2) between female and male students performances in the FMCE and mechanics average marks are 0.003 ($p<0.05$) and 0.336 ($p<0.05$) respectively. This implies that there are statistically significant differences between male and female students' performances in FMCE tests. However, there are no significant differences between male and female student performance in the mechanics examinations, with males performing better than the females with the exception of questions 8-10.

Conclusions and Rrecommendations

The study shows that there is no statistically significant gender differential in physics performance in South Africa as indicated by mechanics examinations results. However, the FMCE revealed that there are significant differences between male and female students performance in conceptual questions, with males outperforming females. We do not know at this stage why the two instruments provide different results and hence a follow-up research that probes this question is necessary. However, student performances in mechanics examinations tend to differ from the FMCE because these examinations do not only measure conceptual understanding, but also test the memorization skills. As Naidoo cited in Netswera and Mathabe (2006) points out, teaching and learning methods in South Africa were designed to blunt the edges of an enquiring mind by subjecting students to what is referred to as 'banking', whereby the teacher provides information and the student receives through memorization and regurgitation (Naidoo 2003 in Netswera and Mathabe 2006). Such memorization might be the one that leads to poor performance in conceptual questions found in the FMCE. A large portion of the mechanics examinations cover either derivation questions or calculations questions as indicated in Table 3.

Table 3: The Percentage Mark of the Exam Question Paper That Covers Content Area Similar to That Covered by the FMCE for Each Institution (Rounded)

	Institution 2	**Institution 3**	**Institution 4**	**FMCE**
Newton's first and second laws	0	3	16	15
Gravity (force and / or acceleration)	0	10	9	13
Kinematics graphs	0	0	0	45
Newton's third law	0	1	3	21
Inclined plane	0	3	0	2
Acceleration	26	9	6	
Total percentage	**26**	**26**	**36**	**96**

In line with the South African government's goals of gender equity, we suggest that female students should be encouraged to take science careers since their performance is as good as that of their male counterparts when measured using the usual university class examinations. Although the results of this study show no statistically significant difference in performance between the two genders in mechanics examinations, we suggest that intervention courses be put in place for female students to enable them to perform at par with the male students especially when conceptual questions are included in the examination.

A partial limitation to this research is that this study could not probe among others racial and rural-urban differentials which were central factors in the historic marginalization project of the apartheid era as cited in the literature. This study finds it necessary and therefore recommends that a probe of the influence of these two factors among others on the performance of physics be carried out in the future. A qualitative study that would seek to verify access to research equipment and the level of training and exposure of high school teachers and university lecturing staff is also necessary. Future studies could also consider performance of learners who matriculate in inclusive or multiracial education schools that were introduced after 1994.

REFERENCES

Amstrong, Sue. 1995. Skills shortage blights South Africa's future. New Scientist. 147(1985):9.

Chadwick, Bruce A., Howard Bahr, and Stan L. Albrecht. 1984. Social Science Research Methods. Prentice-Hall: New Jersey.

Department of Science and Technology. 2006. Keynote address by the Minister of Science and Technology, honorable Mosibudi Mangena, at the 2006 South African Women in Science Awards, held at the Kyalami Castle.

Department of Science and Technology. 2007. National Human Capital for Science Engineering and Technology Plan. Presentation to the Portfolio Committee on Science and Technology, 6 March 2007.

Ding, N., and E. Harskamp. 2006. How partner gender influences female students' problem solving in Physics Education. Journal of Science Education and Technology, 15(5):331-343.

Dzama, Emmanuel, N. N., and Jonathan F. Osborne. 1999. Poor performance in science among African students: An alternative explanation to the African worldview thesis. Journal of Research in Science Teaching, 36(3):387-405.

Editorial. 2005. Why so few choose physics: An alternative explanation for the leaky pipeline. American Journal of Physics, 73(7):583-586.

El Hassan, Karma. 2001. Gender issues in achievement in Lebanon. Social Behavior and Personality, 29(2):113-124.

Frost, Suzie, Michael Reiss, and Jenny Frost. 2005. Count me in! Gender and minority ethnic attainment in school science. School Science Review, 86(316):105-112.

Kortemeyer, Gerd. 2009. Gender differences in the use of an online homework system in an introductory physics course. Physical Review Special Topics – Physics Education Research, 5(010107):1-8.

Kost, Lauren E., Steven J. Pollock, and Noah D. Finkelstein. 2009. Characterizing the gender gap in introductory physics. Physical Review Special Topics – Physics Education Research,5(010101):1-14.

Kost-Smith, Lauren E., Steven J. Pollock, and Noah D. Finkelstein. 2010. Gender disparities in second-semester college physics: The incremental effects of a "smog of bias". Physical Review Special Topics – Physics Education Research, 6(020112):1-17.

Lorenzo, Mercedes, Catherine H. Crouch, and Eric Mazur. 2006. Reducing the gender gap in the physics classroom. American Journal of Physics, 74(2):118-122.

Mallow, Jeffry, Helge Kastrup, Fred B. Bryant, Nelda Hislop, Rachel Shefner, and Maria Udo. 2010. Science anxiety, science attitudes, and gender: Interviews from a binational study. Journal of Science Education and Technology, 19:356369.

Mama, Amina. 2006. Pursuing gender equity in the African University. International Journal of African Renaissance Studies, 1(1):53-79.

McMillan, James H., and Sally Schumacher. 2001. Research in Education: A Conceptual Introduction, 5th ed., Longman: New York.

Miller, Delbert C., and Neil J. Salkind. 2002. Handbook of Research Designs and Social Measurement. 6th edition Sage Publications, Inc. Thousand Oaks.

Naidoo, Kumi. 2003. Civil Society, Governance and Globalisation. Paper presented at the World Bank headquarters in Washington DC, 10 Feb 2003.

Netswera, Fulufhelo G., and Neo Mathabe. 2006. A pervasive apartheid? An analysis of changing higher education in South Africa and its relationship with the State. Journal of Educational Administration and History, 38(1):29-40.

Reid, Norman, and Elena A. Skryabina. 2003. Gender and Physics. International Journal of Science Education, 25(4):509-536.
Reis, Sally M., and Sunghee Park. 2001. Gender differences in high-achieving students in math and science. Journal for the Education for the Gifted, 25(1):52-73.
Robertson, Laura A. 2006. Why are there so few female physicists? The Physics Teacher, 44:177-180.
Rolin, Kristina. 2008. Gender and physics: feminist philosophy and science education. Science and Education, 17:1111-1125.
Sharma, Manjula D., and James Bewes. 2011. Self-monitoring: Confidence, academic achievement and gender differences in physics. Journal of Learning Design, 4(3):1-13.
South African history online explains the academic period that preceded Bantu Education, the Bantu Education system and its consequences [cited August 2012]. Available from http://www.sahistory.org.za; INTERNET
Stadler, Helga, Reinders Duit, and Gertraud Benke. 2000. Do boys and girls understand physics differently? Physics Education, 35(6):417-422.
Tai, Robert H., and Philip M. Sadler. 2001. Gender differences in introductory undergraduate physics performance: university physics versus college physics in the USA. International Journal of Science Education, 23(10):1017-1037.
Thornton, Ronald K., and David R. Sokoloff. 1998. Assessing learning of Newton's laws: The Force and Motion Conceptual Evaluation. American Journal of Physics, 66(4):228-351.
Walker, Melanie. 1998. Academic identities: Women on a South African Landscape. British Journal of Sociology of Education, 19(3):335-354.
Wyer, Mary. 2003. Intending to stay: Images of scientists, attitudes toward women, and gender as influences on persistence among science and engineering majors. Journal of Women Minorities in Science and Engineering, 9:1-16.

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