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Examining science performance of South African Grade 9 learners in TIMSS 2015 through a gender lens

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It is widely acknowledged that understanding of science is key to becoming global citizens and to embrace technological advancements. Although research suggests that girl's performance in science has improved over the years, there are still concerns about the under-representation of women in science, technology, engineering and mathematics (STEM) careers in most African countries, including South Africa. Variability in science performance according to gender is still an unresolved issue. In this study we aimed to examine the relationship between gender and science item achievement of Grade 9 South African learners in the Trends in International Mathematics and Science Study (TIMSS) 2015. We used data collected by TIMSS 2015. The data were further analysed using International Database (IDB) analyser and *t*-test statistics. The results show that in general gender did not influence learner achievement in most of the test items. However, the findings indicate that girls performed better than boys in most of the questions in all 4 content domains and in the knowing and reasoning cognitive domains. The study highlighted that gender had a limited effect in the manner in which the girls and boys answered the different test items. The observed gender differences in the content domains could be related to socio-cultural environments and learning experiences.

Keywords: gender; science achievement; science performance; TIMSS 2015; variability

Introduction

In today's world, it is crucial for learners to develop an understanding of science. This understanding would enable them to make informed decisions as knowledgeable citizens in a rapidly changing world about issues related to climate change, technological advancements, and treatment of diseases. In addition, there is greater demand for students to pursue careers in science, technology and engineering (Amelink, 2009; Baye & Monseur, 2016; Brotman & Moore, 2008; Moletsane & Reddy, 2011; Rop, 1998). South Africa is a country characterised by social and educational inequalities which are reflected in the wide score distribution in the results from TIMSS 2015. The range in score distribution is greater in science than in mathematics. South African learners performed very poorly in mathematics and science in the first administration of TIMSS in 1995; as well as in 1999, 2003 and 2011. However, between 2003 and 2015, the performance of South African learners in both mathematics and science had improved (Reddy, Visser, Winnaar, Arends, Juan, Prinsloo & Isdale 2016).

In terms of gender, Mullis, Martin and Loveless (2016) analysed gender-related trends in children's performance and draw attention to the shift in science performance from 1995 to 2015: from boys displaying a significant advantage and out-performing girls in most countries at Grade 8, to girls achieving higher in 2015. This performance suggests decreasing gender gaps in science performance. Similarly, in the South African context, Reddy et al. (2016) contend that boys performed much better than girls in science in TIMSS 2003; while the science performance of girls improved in TIMSS 2011 and seemed to match that of boys. However, in 2015 girls performed better than boys in science. It is thus pertinent to examine the relationship between gender and student achievement in science, as well as the variability in science performance, in a South African context.

Bofah and Hannula (2015) draw attention to the relationship between motivational beliefs and gendered performance and argue that social and cultural barriers result in gender-related motivational belief and achievement. This belief served as the rationale to conduct a secondary analysis of science achievement of Grade 9 learners in TIMSS 2015, adopting a "gender lens" to examine gender differences in the variability of Grade 9 learner performance. Findings from TIMSS 2011 indicate that the performance of girls and boys in science was similar (Reddy et al., 2016). Although more females currently participate in science, Dlodlo and Beyers (2009) contend that gender issues in science education still needs to be resolved. Globally, women are still greatly underrepresented in science, engineering and technology. Moletsane and Reddy (2011) assert that, in South Africa and worldwide, the under-representation of females in STEM fields is a concern and promoting gender equity and equality a major priority. Furthermore, Brickhouse, Lowery and Shultz (2000); Brotman and Moore (2008) and Rop (1998) argue that there is still isolation and marginalisation of females in science education. These studies highlight that gender inequalities persist in STEM subjects regarding the lower numbers of females studying these subjects as well as low numbers of females working in these areas, especially in leadership positions. This pattern suggests that improvement in the achievement of females at school level is not translating into improvement of achievement of females at tertiary level and increased opportunities for females in STEM fields. This situation is cause for concern and points to the need for this study, which will contribute to knowledge in this essential field. Therefore, gender-related variations in science performance over the years stimulated interest in the topic.

The aim of this study was to examine the relationship between gender and science item achievement of Grade 9 South African learners in TIMSS 2015. The challenge within gender studies lies in showing how each test item can be answered differently based on the knowledge domains. In particular, this study aimed to conduct a secondary analysis of the content domains of science items, namely, biology, chemistry, physics and earth science, and to highlight the relationship between gender and science achievement in these content domains. This study also focussed on the cognitive domains namely, knowing, applying and reasoning through a gender lens.

Background

The International Association for the Evaluation of Educational Achievements (IEA) first implemented TIMSS in 1995, and thereafter every four years in 1999, 2003, 2007, 2011 and 2015. However, TIMSS was not implemented in South Africa in 2007. TIMSS was developed as an international comparative study to measure mathematics and science achievement of Grade 4 and Grade 8 learners, although in South Africa Grade 9 learners participated instead of Grade 8 learners. TIMSS items are broadly aligned with mathematics and science curricula of participating countries and are designed to assess the quality of mathematics and science teaching and learning. Background information of learners and teachers as well as contextual information of schools are used to explain trends in learner's achievement in participating countries. As a benchmark, TIMSS allows different countries to compare their educational systems, including curricula, teaching and learning, and provides valuable information for educational policy or curricular reform to improve learner achievement (Mullis, Martin & Loveless, 2016).

Gender equality and science performance

In this study we adopted the United Nations Educational, Scientific and Cultural Organization's (UNESCO's) notion of gender equality as "boys and girls experiencing the same advantages or disadvantages in attending school, receiving teaching methods, curricula, and academic orientation, and producing equal learning achievements and subsequent life opportunities" (Moloi & Chetty, 2011:2). According to Moletsane and Reddy (2011), gender equality is an attribute of democratic countries and equity in education serves as a development indicator.

The Education for All (EFA) Goals and Millennium Development Goals (MDG) emphasise the importance of gender equality in education (Moloi & Chetty, 2011). Gender equality in educational opportunities was a key educational goal to be achieved by 2015 (UNESCO, 2011). Mullis, Martin, Fierros, Goldberg and Stemler (2000) contend that, in many countries, the average science achievement of 8th grade boys was significantly higher than that of girls. While some studies have shown that males perform better than females in science, others have indicated that there is no gendered difference in science achievement (Amelink, 2009; Reddy et al., 2016). In other countries, attempts have been made to track learners' performance in science in elementary school and high school; however, the findings of these studies have been inconclusive (Lin, 2015). Baye and Monseur (2016) also draw attention to such contradictions and to misrepresentations of gender differences in performance. With this study we aimed to shed light and elaborate on such controversies in gendered science achievement.

Moloi and Chetty (2011) assert that between the years 2000 and 2007, generally, in South African primary schools at Grade 6 level there was a gender balance in school enrolment. This finding is reassuring and suggests that efforts to maintain gender equality in primary school education in South Africa are being achieved. Furthermore, Moloi and Chetty (2011) contend that generally girls performed better than boys in Grade 6 mathematics. The South African Department of Basic Education presented the Matric results in mathematics and physical sciences from 2010 to 2013 and highlighted that although more girls wrote mathematics and physical sciences, boys performed better than girls. This suggests that there were gender inequalities with regard to enrolments and performance in mathematics and physical sciences at secondary school level. This decline in the performance of girls from primary to secondary school could be attributed to the poor quality of their learning experiences, which affect their learning achievements (Moletsane, 2010 in Rarieya, Sanger & Moolman, 2014). Also, the lower performance of girls in mathematics and physical science at secondary school has a negative effect on their participation in the sciences at tertiary level and employment in science-based careers. A challenge facing South African higher education institutions is to increase the enrolment of females. Although higher education institutions have equity plans, employment equity and transformation committees in place, gender inequity is still prevalent. Mayer-Smith, Pedretti and Woodrow (2000 in Dlodlo & Beyers, 2009) argue that a gender inclusive learning atmosphere stimulates equal participation between males and females and is encouraged by good teaching practices and social environments.

Bofah and Hannula (2015:1) investigated the background constructs of gender and compared TIMSS 2011 data in five African countries. Their findings were "consistent with cultural stereotypes that boys rated their mathematics competence higher than girls." They also mention the "paradoxical" and "perplexing" controversies in findings from cross-cultural studies and the negative relationship between self-belief and mathematics achievement. With this study we aimed to examine the relationship between gender and science achievement of Grade 9 South African learners in TIMSS 2015.

Various reasons are suggested for girls' poor performance in science. For example, cultural stereotypes of roles in science (Debacker & Nelson, 2000), girls' lack of exposure to science-related activities outside the classroom (Kahle, Parker, Rennie & Riley, 1993), decrease in girls' science ability perception over time (Jovanovic & King, 1998), gender biases of teachers (Greenfield, 1996), and differences in cognitive abilities (Spelke, 2005). Jacobi, Wittreich and Hogue (2003) claim that parents' actions, beliefs and gender roles in science assigned to girls also influence children's attitudes and achievement in science.

As in TIMSS 2015, the concept "curriculum" will be used as an organising concept in this study to examine educational opportunities offered to learners as well as the factors influencing how students engage with these educational opportunities. The TIMSS Curriculum Model outlines three components: the intended curriculum, the implemented curriculum and the attained curriculum. In South Africa, the Curriculum and Assessment Policy Statement (CAPS) represents the intended curriculum and describes the science content that learners are expected to learn. The implemented curriculum describes how teachers organise and deliver the curriculum to facilitate learning in the classroom. The attained curriculum represents what learners have learned and their conceptions of learning. This study adopted the assessment framework of TIMSS 2015, which is structured according to two dimensions:

- Content dimension, specifying the subject matter to be assessed; and
- Cognitive dimension, specifying the thinking processes to be assessed.

The content dimensions include biology, chemistry, physics and earth science; while the cognitive dimensions include knowing, applying and reasoning. The knowing dimension assesses "student's knowledge of facts, relationships, processes, concepts and equipment." The reasoning domain includes items which engage students in analysing data and information, drawing conclusions and applying their understanding to new contexts. Items in the applying dimension engage students in applying knowledge, relationships, concepts, processes, equipment and methods to contexts of teaching and learning science (Mullis & Martin, 2013:55–56).

The performance of Grade 9 girls and boys in the content domains of science items, namely, biology, chemistry, physics and earth science, as well as the cognitive domains of knowing, applying and reasoning were analysed. Gendered variability in their performance in these content and cognitive domains are highlighted.

Methodology

In this research study we adopted a quantitative methodological approach and involved secondary research since it was based on secondary analysis of quantitative data from the TIMSS 2015 dataset. Bless, Higson-Smith and Sithole (2013:57) describe secondary research as researcher using "data that has been collected for some other reason to answer a new research question." The primary data were collected for TIMSS 2015, which was conducted by the IEA to assess international comparative trends in mathematics and science achievement. TIMSS 2015 measures science knowledge and skills of Grade 9 learners. TIMSS assessment instruments are designed to align with the science curriculum taught, or the implemented curriculum, and comprises science items categorised into content domains and cognitive domains. Assessment instruments are developed in English, use two item formats, namely, multiple choice and constructed response. Achievement is reported according to average science scale scores for all participating countries highlighting TIMSS benchmarks.

Secondary analysis of the TIMSS 2015 Grade 9 science data was done to highlight the relationship between gender and science achievement of Grade 9 South African learners. In particular, the content domains or dimensions (biology, physics, chemistry and earth science) of the TIMSS 2015 science items were analysed to examine achievement in each content domain according to gender. The cognitive domains or dimensions (knowing, applying and reasoning) of the TIMSS 2015 science items were also analysed in relation to gender.

The research question that this study intended to address was: What is the relationship between gender and students' science achievement scores in Grade 9 South African learners?

The research sub-questions that guided this study were:

1) What is the relationship between gender and Grade 9 learners' science achievement scores in the biology and earth science content domains in TIMSS 2015 science items?
2) What is the relationship between gender and Grade 9 learners' science achievement scores in the physical science and chemistry content domains in TIMSS 2015 science items?
3) What is the performance of Grade 9 science learners in relation to the different cognitive domains?

Data for this study were drawn from the TIMSS 2015 dataset. The South African TIMSS 2015 sample comprised of 292 schools, 12,500 learners, 334 mathematics teachers and 331 science teachers from schools grouped into three categories, namely, no-fee paying, fee-paying public, and independent schools (Reddy et al., 2016). The almanacs are text files that display a summary of unweighted statistics for each variable in the background questionnaire for each participating country. TIMSS 2015 data almanacs for Grade 9 science learners were analysed and those items whose answers had been released were selected and captured for further analysis. In total, 146 test items with the answers were identified. The data were captured on Microsoft Excel. Responses were arranged by gender. The topics were classified into four content domains or dimensions: chemistry, physics, biology and earth science. The cognitive domains or dimensions – knowing, applying and reasoning – were also identified and captured. The analysis involved printing of hard copies for each question and classifying the questions based on the four content domains, which were already marked for each question. The TIMSS data report on group scores. The average percentages for boys and girls were classified and captured using three categories of scores: 10 to 20%, 21 to 30% up to 71% and above.

Of the 146 questions with answers, only 39 questions were multiple-choice questions with four alternative responses; these questions were further analysed using IEA IDB Analyser 4.0.30 (IEA, 2017). The analysis excluded questions where no correct answers were revealed. Those cases where a choice of two to three alternatives was suggested were also excluded from this analysis. The analysis was run with 39 multiple choice questions that included the four alternatives (A, B, C, D) as possible answers and the results for boys and girls were captured in the tables. The dependent variable in this study was the TIMSS 2015 Grade 9 science achievement score.

Participants

In South Africa, the participants were Grade 9 science learners. The TIMSS 2015 had 12,513 participants, 6,426 boys and 6,087 girls. However, data were captured for 1,750 participants. The results presented in this paper were based on this sample. The rest of the data were recorded as missing for most of learners (Reddy et al., 2016).

Data Analysis

The data for this study were obtained from South African Grade 9 learners who participated in the TIMSS 2015. The students' questionnaire was further analysed using IEA IDB Analyser 4.0.30 (IEA, 2017). Data were analysed using gender Plausible Values (PVs) by item, learner weights and plausible values. In this analysis, the gender of the learners and the item under investigation were selected as groupings. We also selected Excel as the output. The analysis was run using the Statistical Package for the Social Sciences (SPSS) that is embedded in the IDB analyser and the outcome of the analysis generated *t*-test statistics values. The statistical tables were used to determine the *p*-values. The degrees of freedom for *t*-test are above 1,500 so it is reasonable to use normal approximations (asymptotical properties of *t*-test).

A *t*-test is a parametric test used to analyse group differences based on the same sample and is designed to evaluate the statistical significance of the difference between the mean of two groups (Bureau, 2012). Accordingly, this test was used to determine whether there was a statistically significant relationship between gender and learners' achievement scores among South African Grade 9 science learners.

Findings

In order to assess the relationship between gender and learners' achievement scores among South African Grade 9 learners, a *t*- test of independence was used.

Thus, we intended to verify the following hypotheses:

H_0: Learners' gender and learners' achievement are independent i.e. there is no relationship between them.

H_1: Learners' gender and learners' achievement are dependent i.e. there is a relationship between them.

We concluded that at the 5% significance level, those questions with *p*-values less than 0.05 were statistically significant and we rejected H_0 for these pairs (i.e. only for the statements with *p*-values < 0.05, in Table 1). In other words, where the *p*-values were less than 0.05, there was a statistically significant relationship between gender and learners' science achievement scores of South African Grade 9 learners. The results are presented in Table 1 and Table 2.

Table 1 highlights gender differences in 16 questions in the biology and earth science content domains. The results in Table 1 address research question 1.

Table 1 Gender and Grade 9 learners' performance in the biology and earth science content domains in the South African TIMSS data

	Correct responses (%)		*N*	*t*-statistics	
Item focus content area	Girls	Boys	Girls (Boys)	*t*-values	*z*-values
Characteristics of young rabbits	**57.86**	**42.14**	**941(814)**	**3.10**	**0.0020**
Earth's continent are moving	**56.51**	**43.49**	**899(819)**	**2.99**	**0.0028**
Climate and Geography	**42.11**	**57.89**	**859(818)**	**2.51**	**0.0120**
Symbiosis between two organisms	**58.37**	**41.63**	**927(826)**	**2.14**	**0.0324**
Acquired characteristics	**56.05**	**43.95**	**941(823)**	**2.00**	**0.0455**
Healthy and balanced meal	**59.59**	**40.41**	**940(835)**	**3.79**	**0.0002**
Function lungs-skin kidney share	54.92	45.08	899(831)	1.53	0.1260
Classify animal with these features	53.80	46.20	902(819)	0.98	0.3270
Cell development in young animals	49.75	50.25	936(802)	0.06	0.9204
Photosynthesis and sunlight	47.44	52.56	871(805)	0.82	0.4180
Influenza cause	48.52	51.48	944(826)	0.66	0.5092
Biceps and triceps	54.33	45.67	945(833)	1.64	0.1010
Why people shiver when cold	51.59	48.41	941(815)	0.60	0.3096
Fossils in rock layers	54.62	45.38	923(818)	1.59	0.1118
Greenhouse on Mars	53.21	46.79	927(825)	0.94	0.3472
Solar system changing seasons	49.25	50.75	885(808)	0.29	0.7718

Note. Items marked in bold showed significant difference.

The results in Table 1 indicate that gender had a significant effect on the manner in which learners answered the question about characteristics of young rabbits (difference in mean score = 15.72%, $t = 3.10$, $p = < 0.002$). The girls (57.86%) gave more correct answers than boys (42.14%). The result suggests that girls had a better understanding of the question on characteristics of rabbits.

The results also show a significant link between gender and answering the question on Earth's continents moving (difference in mean score = 14.37%, $t = 2.99$, $p = < 0.0028$). The results show that girls (56.51%) outperformed boys (43.49%). The results in Table 1 indicate that gender had a significant effect on how learners answered the question on climate and geography (difference in mean score = 15.78%, $t = 2.51$, $p =$ **0.0120**). The results illustrate that boys (57.89%) demonstrated a better understanding of climate and geography than girls (42.11%).

The results also indicate a significant link between gender and answering the question on symbiosis between two organisms (difference in mean score = 16.74%, $t = 2.14$, $p =$ **0.0324**). The results show that girls (58.37%) performed better than boys (41.63%).

The results also show a significant link between gender and answering the question on acquired characteristics (difference in mean score = 16.74%, $t = 2.00$, $p =$ **0.0455**). The girls (56.05%) displayed a better understanding of acquired characteristics of animals than boys (43.95%).

In addition, the results show a significant difference between gender and answering the question on healthy and balanced meals (difference in mean score = 19.18%, $t = 3.79$, $p =$ **0.0002**). The results show that girls (59.59%) outperformed boys (40.41%).

These results highlight that for the six questions where there was a significant difference in content domains in biology and earth science, girls performed better in five of the six questions.

There was no statistically significant difference in achievement for girls and boys on questions pertaining to (a) function lungs-skin kidney share, (b) classify animal with these features, (c) cell development in young animals, (d) photosynthesis and sunlight, (e) influenza cause, (f) biceps and triceps, (g) why people shiver when cold and (h) fossils in rock layers.

Table 2 highlights gender differences in 23 questions in the physics and chemistry content domains. The results in Table 2 address research question 2.

Table 2 Gender and student's performance in physics and chemistry content domains in the South African TIMSS data

	Correct responses (%)		*N*	*t*-statistics	
Item focus content area	Girls	Boys	Girls (Boys)	*t*-values	*z*-values
Example of lever	**58.43**	**41.57**	**860(791)**	**3.19**	**0.0014**
Cause distilled water taste	**56.88**	**43.12**	**932(793)**	**2.10**	**0.0358**
Example of chemical change	**61.05**	**38.95**	**937(823)**	**4.77**	**0.0002**
Properties of baking soda	**54.94**	**45.06**	**934(819)**	**1.90**	**0.0574**
Gas inside ping-pong ball	**56.14**	**43.86**	**932(814)**	**2.43**	**0.0150**
Chemical reaction definition	55.37	44.63	900(825)	1.54	0.1236
Metal rod in basin of water	47.77	52.23	887(822)	0.53	0.5962
Which one is a mixture?	44.49	55.51	883(810)	1.23	0.2186
Formation of oil	55.35	44.65	931(832)	1.80	0.0718
Toy car's distance over time	51.58	48.42	886(810)	0.61	0.5418
Toy car powered by battery	54.13	45.87	923(815)	1.73	0.0836
Property of non-metals	53.93	46.21	936(793)	1.64	0.5222
Particles in samples X and Y	52.30	47.70	923(794)	0.76	0.4472
Temperature of three containers	49.60	50.40	926(796)	0.01	0.9920
Water and tea graphs	51.16	48.84	936(813)	0.45	0.6528
Water pressure on fish	54.65	45.35	926(809)	1.60	0.1096
Artesian water moving up pipe	48.33	51.67	917(788)	0.70	.4840
Artesian water: difference flow	46.96	53.04	909(779)	1.03	0.3030
Flashlight on blue balls	50.80	49.20	923(803)	0.29	0.7718
Energy for water cycle	54.39	45.61	931(802)	1.87	0.0614
Moving log with a bar and stone	46.59	53.41	909(787)	1.41	0.1586
Gravitational pull of moon	46.68	53.32	843(763)	0.80	0.4238
Electromagnet attracting needles	49.68	50.32	932(818)	0.15	0.8808

Note. Items marked in bold showed significant difference.

There was a significant link between gender and the likelihood to answer the question on an example of a lever correctly or not. The difference was 16.86% (t = 3.19%, p = **0.0014**). More girls (58.43%) were correct than boys (41.57%).

These results also highlight that there was a significant impact between gender and answering the question about the causes of distilled water taste correctly or not. The difference was 13.76% (t = 2.10; p = **0.0358**). The girls (56.88%) outperformed the boys (43.12%).

There was a significant link between gender and answering the question on example of chemical change correctly or not. The difference was 22.1%, (t = 4.77; p = **0.0002**). The results show that girls (61.05%) understood the question better than boys (38.95%).

The results also show that there was a significant link between gender and answering the question on properties of baking soda (difference in mean score = 9.88%, t = 1.90, p = **0.0574**). The girls (54.94%) demonstrated a better understanding of the properties of baking soda than boys (45.06%).

There was a significant effect between gender and answering the question on gas inside a ping-pong ball (difference in mean score 12.28%, t = 2.43, p = **0.0150**). The girls (56.14%) gave more correct answers than boys (43.86%).

The results in Table 2 show that only five of 23 test items were significantly different in terms of gender performance. In these five questions, there was a significant difference between the performance of girls and boys. Overall the girls' performance was much better than that of boys.

The results show that gender had no significant impact on the manner in which the Grade 9 science learners answered the remaining questions. These questions required learners to demonstrate an understanding of different aspects of physical sciences: (a) chemical reaction definition, (b) metal rod in basin of water, (c) which one is a mixture?, (d) formation of oil, (e) toy car's distance over time, (f) toy car powered by battery, (g) property of non-metals, (h) particles in samples X and Y, (i) temperature of three containers, (j) water and tea graphs, (k) water pressure on fish, (l) artesian water moving up pipe, (m) artesian water: difference flow, (n) flashlight on blue balls, (o) energy for water cycle, (p) moving log with a bar and stone, (q) gravitational pull of moon and (r) electromagnet attracting needles.

In order to understand Grade 9 science learners' achievement and how they performed based on different cognitive domains, the average achievement scores for this analysis were obtained from the TIMSS 2015 almanacs or record of results. In total, 146 questions with released answers were retrieved and the scores tallied. The questions that were analysed for average performance were distributed from the four content domains: biology, chemistry, physics and earth science. With regard to the cognitive domains; there were 74 questions that focused on knowing, 58 questions focussed on applying and only 14 questions focused on reasoning. The frequency graph was drawn based on the average scores of the performance of Grade 9

South African science learners for the different cognitive domains, which addresses research question 3.

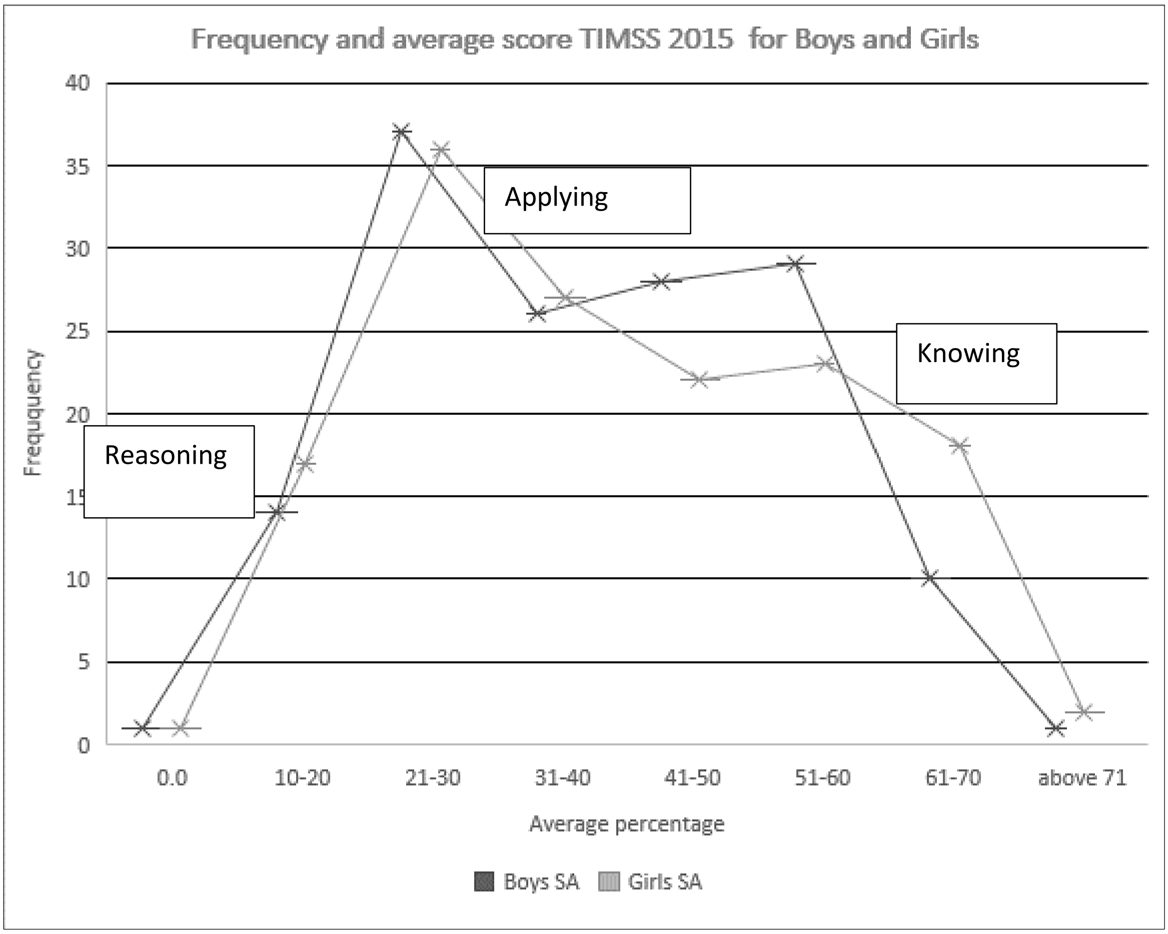

Figure 1 Performance of Grade 9 science learners by gender across cognitive domains in the South African TIMSS data

From Figure 1 it is evident that the South African Grade 9 boys underperformed in TIMSS 2015 in the cognitive domain of reasoning, within the lowest score, which ranged from 10% to 20% and 21% to 30%, and they performed better than girls between the average scores of 41 to 50% and 51 to 60% in the cognitive domain, applying. The girls seem to have performed better than boys on the average score of 60 to 70% and 71% and above in the cognitive domain, knowing. It is evident that boys also underperformed in questions in the cognitive domain, knowing.

Discussion

In this study we examined the relationship between gender and science achievement of Grade 9 South African learners in TIMSS 2015. The advantage of countries participating in international studies such as TIMSS 2015 is that gaps in the teaching and learning can be noted and countries can have a platform to compare their education systems. The findings assist countries to learn from each other. Some of the countries like Jordan, Hong Kong and Malaysia that participated in the TIMSS 2015 study have used the findings to revise their curricula (Ababneh, Al-Tweissi & Abulibdeh, 2016; Mullis, Martin, Goh & Cotter, 2016). At a global level, the TIMSS 2015 results showed that there was no significant difference between the performance of boys and girls in Grade 9 science. However, the South African Grade 9 science learners, both boys and girls, performed well below the international average score (500) with an average score of 358 (Reddy et al., 2016).

This study has shown that girls outperformed boys in the life sciences, earth sciences, physics and chemistry content domain questions. These results resonate with the findings of Mullis, Martin and Loveless (2016), as well as Reddy et al. (2016), which draw attention to higher achievement of girls in science. The performance of boys in most of the questions was poor. These findings are in contrast with the findings of Mullis et al. (2000) which suggest higher average science achievement of boys.

The results might indicate that the teaching of science has focused on uplifting the girl child at the expense of boys. For example, the focus of teacher training and what the literature advocate for is the improvement of girls in mathematics and science (Shel, 2007). However, in this study we found that in the earth science content domain questions performance of girls was only slightly better than for boys, which corresponds with Amelink's (2009) study that indicated no gendered difference in science achievement.

In the physics and chemistry content domains (Table 2), results highlight that girls performed better than boys. Girls gave more correct answers in questions such as example of a lever, cause of distilled water taste, example of chemical change, properties of baking powder and gas inside a ping-pong ball. This finding highlights gender differences in chemistry, physics, earth science and life sciences content domains and draws attention to the importance of teachers teaching in lower secondary school to acknowledge poor performance of learners in science (Shel, 2007). In cases where the science teachers are female, it is possible that a lack of proper role models in the teaching of science contributes to gendered differences in science performance (Hadjar, Krolak-Schwerdt, Priem & Glock, 2014). The findings of this study show that girls performed better than boys for selected science test item in the TIMSS 2015 Grade 9 science tests. However, the influence of gender on science performance in TIMSS 2015 is limited compared to in TIMSS 1995 and TIMSS 2003 where boys performed significantly better than girls (Mullis, Martin & Loveless, 2016; Reddy et al., 2016).

These findings can be explained, in the South African context, by improvement in teacher qualifications, experience and an increase in the number of female natural sciences teachers over the years who could serve as role models for girls to perform better. Dee (2006:73) argues that "[w]hen a class is headed by a woman, boys are more likely to be seen as disruptive. When taught by a man, girls were more likely to report that they did not look forward to a subject." The improvement in the availability of school resources such as textbooks and minor improvements in learning climate at home and school could also possibly have contributed to an improvement in girl's science performance. However, despite the shift and improvement of girl's performance in science at secondary level, this has not translated into increased participation and performance of females at tertiary level and in STEM careers. This indeed is an area that warrants further research.

A further concern is that in the questions where girls performed better than boys, none of the scores was above 75%. This indicates that the teaching of science is still a challenge in South Africa and there are more issues beside gender that still need to be addressed (Mickelson, Nkomo & Smith, 2001).

The overall findings in this study suggest that girls were more often correct than boys in the selected TIMSS 2015 science items. This resonates with Reddy et al.'s (2016) finding that South African girls outperformed boys in TIMSS 2015. The findings in this study are different to those observed in Australia in TIMSS 2003 where boys outscored girls (Thomson, 2008). Baye and Monseur (2016) also found that boys were more frequently the highest performers in mathematics. These results seem to contradict the findings of Debacker and Nelson (2000), Kahle et al. (1993) and Spelke (2005) which suggest cultural stereotypes of roles in science, lack of exposure to science-related activities outside the classroom and differences in cognitive abilities; as reasons for girls' poor performance in science.

Concerning the knowing, applying and reasoning cognitive domains, we found that girls performed better in the knowing and reasoning cognitive domains while the boys performed better in the applying cognitive domain. In addition, Bofah and Hannula (2015) found that cultural stereotypes caused gender difference in learners' performance, which could explain the gendered variability in the content domains and cognitive domains in this study. The findings also suggest that socio-cultural contexts and childhood and schooling experiences influence the science performance of boys and girls, and that it is important for teachers to acknowledge this in their teaching and assessment tasks. Gender stereotypes and roles are still embedded in South African society where science careers are viewed as a male domain (Juan, Hannan & Namome, 2018), which could explain the poor representation of females in STEM careers. It is, therefore, important for teachers to be gender sensitive and motivate girls to engage actively in science lessons. Science teachers could invite female role models to encourage girls to pursue science careers and build their self- confidence.

It is of great concern that the South African Grade 9 science learners scored below 505 in most of the questions asked in the study (Reddy et al., 2016). This might be because some of the learners obtained very low scores since schools in South Africa do not have equal support in terms of teaching resources and teacher quality (Spaull, 2013). An additional concern is that the number of learners selecting incorrect responses is quite high (see Table 1 and Table 2). This might be explained by the manner in which science is taught in the implemented curriculum in lower secondary grades in South Africa. The introduction of outcomes-based education also influenced the quality of science teaching in lower classes with greater emphasis on assessments and examinations than on conceptual development (Spaull, 2013).

Conclusion

In this study we reported on the relationship between gender and science achievement of Grade 9 South African learners in TIMSS 2015. The main finding of this study was that Grade 9 girls performed better than boys in most selected TIMSS 2015 science items and in the life sciences, earth sciences, physics and chemistry content domains. Results also highlight that girls performed better in the knowing and reasoning cognitive domains while boys performed better in the applying cognitive domain. These findings point to the need for teachers and parents to be gender sensitive, address traditional gender stereotypes and encourage girls to pursue STEM careers. The teaching of science in Grade 9 should focus on developing conceptual understanding of concepts. Science teachers should also align the intended curriculum and the implemented curriculum and design relevant assessment tasks to test knowledge and skills.

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Authors' Contributions

JN wrote the introduction, background, literature review and methodology section; DS wrote the data analysis section and presented and analysed the data. Both authors wrote the discussion and conclusion and reviewed the final manuscript.

Notes

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