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Olympiad participation: Problem-solving skills in mathematically gifted disadvantaged learners

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Background: Gifted learners are South Africa's future leaders and investment in the skills of disadvantaged learners would benefit the country.

Objectives: This study investigated whether Olympiad participation could develop problem-solving skills in mathematically gifted disadvantaged learners.

Methods: The methodology of the study was quantitative. A total of 100 mathematically gifted Grade 7 learners from two quintile two schools in the same disadvantaged area of South Africa were exposed either to Olympiad-style questions (South African Mathematics Challenge past papers), or traditional Department of Education worksheets. Five aspects of Study Orientation, including problem-solving behaviour, were assessed using the Study Orientation in Mathematics (SOM) before and after the intervention.

Results: The findings revealed a correlation between success in traditional mathematics and study attitude, study habits, and overall study orientation, as well as an interaction between disadvantage and success in mathematics. The intervention did not increase problem-solving skills. Participants found the Olympiad-type questions unfamiliar and difficult, which is indicative of the limited enrichment opportunities for mathematically gifted learners in disadvantaged areas of South Africa.

Conclusion: Poverty and giftedness were shown to interact: the gifted disadvantaged learners in this study were less disadvantaged by their surroundings than one would expect and conversely had higher mathematics anxiety than expected for their achievement level.

Contribution: This study highlights the need to nurture the skills of mathematically gifted disadvantaged children.

Keywords: mathematically gifted; gifted disadvantaged; problem-solving skills; mathematics Olympiad; South Africa.

Introduction

Gifted disadvantaged learners in South Africa

Gifted children are South Africa's future leaders, scientists and researchers. Gifted children in South Africa are typically 'undervalued and under-served' (Van der Westhuizen, 2007, p. 1), particularly disadvantaged children, who do not have access to quality education. According to Statistics South Africa (2017), 66.8% of children aged 0–17 in South Africa were living below the upper-bound poverty line (UBPL) in 2015. Definitions of giftedness vary from 2% to 5% of the population, which means that roughly 260 000 to 650 000 children in South Africa have untapped potential as both gifted and disadvantaged.

Education potentially facilitates an escape from a poverty 'trap' in South Africa: only 8.4% of adults with higher education are living below the UBPL compared with 79.2% of those with no education and 69.2% of those with only primary school education (Statistics South Africa, 2017). In South Africa, the Department of Basic Education categorises schools according to quintiles or fifths of the population, based on the poverty level of the communities surrounding the schools, with quintile 1 being the poorest, and quintile 5 the richest (Murray, 2017). Quintile 1–3 schools are non-fee-paying. For the purpose of this study, a child attending a non-fee-paying school was defined as disadvantaged. Van Broekhuizen et al. (2016) found that:

> [*W*]hile attending a quintile 1–3 school largely precludes learners from gaining access to university, those who do make it into university tend to perform almost on par with their quintile 4 and 5 counterparts. (p. 66)

This finding implies that investment in the skills of gifted disadvantaged learners at school level (resulting in more learners entering university) would pay off with more university passes.

Identification of the gifted in South Africa

Many difficulties are associated with intelligence testing in multilingual and multicultural countries with widely varying access to education (such as South Africa). The country has 11 official languages, namely English, Afrikaans, and nine African languages (Jordan, 2015; Maree et al., 2011). Although English is the dominant language in business and government in South Africa, 76.9% of the population speaks an African language as a home language (Jordan, 2015). Intelligence quotient (IQ) tests available for African language speakers in South Africa are limited. The New South African Individual Scale (NSAIS) (1962) was translated into isiXhosa in 1988, and from there into four other African languages, and normed on black children from 9 to 19 years of age (Mayaba, 2016). These translations of a 1962 test remain the only IQ tests available in these languages. The Junior South African Individual Scale (JSAIS) (Madge, 1981) was translated into isiZulu and SeSotho in 2010 (Mawila, 2012). However, these versions are not yet commercially available (Health Professions Council of South Africa, 2017). Van Eeden published studies in 1993 and 1997 on black children attending private and former white schools, who were educated in English and took the Senior South African Individual Scale Revised (SSAIS-R) (Van Eeden, 1991) in English. She concluded that norms for environmentally disadvantaged learners should be used when evaluating children whose home language is not the testing language (Cockcroft, 2013).

Non-verbal tests, such as the Raven's Standard Progressive Matrices (SPM), the Naglieri Non-Verbal Ability Test (NNAT) and Form 6 of the Cognitive Abilities Test (COGAT) are often suggested as a culture- or language-fair option for use in multicultural and multilingual societies such as South Africa (Laher & Cockcroft, 2017; Sarouphim, 2009). However, Lohman and Gambrell (2012) found a 7.3 and 9.5 point difference in scores between first- and second-language English speakers and that 'reducing the language demands may actually increase the cultural loading of the test' (Lohman, 2013, p. 274). In South Africa, studies by Israel (2006) and Knowles (2008) found substantial language bias in the Raven's Advanced Progressive Matrices (RAPM) and RPM. Similar results have been found in Zambia and Kenya (Maree 2018).

Problem-solving skills in South Africa

Problem-solving skills are higher-level, creative skills. These skills are beneficial at university and in the workplace (Griesel & Parker, 2009). Good problem-solvers have meta-cognition developed through problem-solving experience (Nieuwoudt, 2015). Mathematics competitions expose learners to problem solving (Engelbrecht & Mwambakana, 2016). Various mathematics competitions are open to learners in South Africa. Most of these competitions are free or have free entry for learners from no-fee schools (South African Mathematics Foundation [SAMF], 2020b; University of Cape Town, 2019; University of Pretoria, 2019; University of Witwatersrand, 2019). There are also several free Olympiad training programmes provided by the SAMF, namely the Siyanqoba training and SAMF Olympiad training (Grades 7–12) (SAMF, 2020a). The South African (SA) Mathematics Challenge is the biggest of these Olympiads for Grades 4–7 learners, with 80 000 learners having participated in 2019 (SAMF, 2020b).

South African learners lack problem-solving strategies and skills, and mathematics textbooks used in South African schools use routine problems (Chirove & Mogari, 2014). The general level of problem-solving skills at school level in South Africa is demonstrated in South Africa's performance in the Trends in International Mathematics and Science Study (TIMSS), which 'assesses a range of problem-solving situations within mathematics, with about two-thirds of the items requiring students to use applying and reasoning skills' (Grønmo et al., 2013). South Africa came in second-last in mathematics (Business Tech, 2016). Additionally, in South Africa, not only learners but also teachers find non-routine problems difficult (Chirove & Mogari, 2014). In a study by Govender (2014b), 14 second-year trainee teachers wrote the Grade 7 SA Mathematics Challenge. Only 28.7% of the trainee teachers scored over 60% (the score required for a Grade 7 learner to progress to the second round of the Olympiad). South African Mathematics teachers even lack basic skills: Venkat and Spaull (2015) found that 79% of South African Grade 6 Mathematics teachers were classified as having content knowledge levels below Grade 6. Maree and Erasmus (2006) stress the need for informal mathematics learning to develop problem-solving skills. This is hard to achieve in a country where parents work long hours and have low levels of mathematics education themselves. Even South Africa's best performers in the TIMSS did poorly in problem solving (Long & Wendt, 2017).

Rationale for the study

Mhlolo (2015, p. 166) identifies mathematical competence as 'the key to the welfare of a nation in a global economy' and warns of two groups that are in high risk of not realising their full potential: mathematically gifted children and economically disadvantaged children. Research in South Africa has largely neglected mathematically gifted disadvantaged children (Stones, 2020). Although there is extensive research on mathematics education in South Africa, 'little research has been done on the impact and efficiency of mathematics olympiads' (Engelbrecht & Mwambakana, 2016, p. 2). There was a gap at the intersection of these two areas of research, namely gifted disadvantaged children and the impact of mathematics Olympiads. There have been no studies on the potential benefits of the SA Mathematics Challenge or Olympiad for gifted disadvantaged children (Stones, 2020). This research aims to fill this gap in the body of knowledge on giftedness.

Research questions

The purpose of this study was to examine the possible effects of Olympiad participation on gifted disadvantaged children, particularly to explore whether Olympiad participation could develop problem-solving skills in mathematically gifted learners from disadvantaged schools. The primary research question was as follows: How valuable is participation in the SA Mathematics Challenge for developing problem-solving skills in mathematically gifted disadvantaged learners? This gave rise to the following secondary research questions:

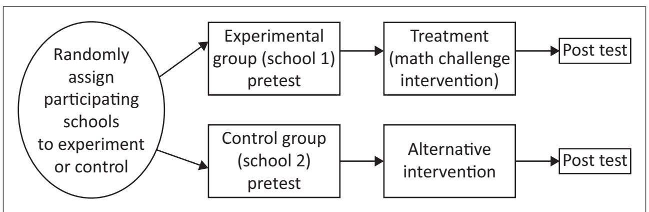
- What are the essential aspects of current (group-based) programmes aimed at enhancing the problem-solving skills of mathematically gifted learners in disadvantaged schools?
- What is the impact of 3 h-long facilitated sessions doing SA Mathematics Challenge past papers on mathematically gifted disadvantaged learners' study orientation in mathematics in general?
- What is the impact of 3 h-long facilitated sessions doing SA Mathematics Challenge past papers on mathematically gifted disadvantaged learners' problem-solving skills in particular?

Research methods and design

Research paradigm and design

This study was viewed through the lens of critical realism (Cruickshank, 2011). To examine matters from multiple cultural stances, research in a multicultural society needs to adapt from a Eurocentric view. The advantage of the pragmatic prism to one's lens is the emphasis on the practical: research does not have to reach an ideal that might be unattainable to contribute to the body of knowledge on gifted education in South Africa, or to benefit gifted disadvantaged children. The methodological approach of the study was quantitative.

As shown in Figure 1, the study utilised a non-equivalent comparison group design, which is a quasi-experimental version of the pretest-posttest comparison group design (Engel & Shutt, 2014). There are two groups in a comparison group design, one of which receives the intervention and one that receives a different intervention. The disadvantage of comparison group design compared to using a traditional control group is that it is a comparison of interventions, rather than comparing an intervention against no intervention. However, it is generally accepted that it is right and ethical to offer both groups some benefit in the study (Maree & Pietersen, 2016).



Source: Adapted from Maree, J.G., & Pietersen, J. (2020). The quantitative research process. In K. Maree (Ed.), *First steps in research* (3rd ed., pp. 184–195). Van Schaik Publishers

FIGURE 1: Non-equivalent comparison group design.

Sampling

Selection of schools

A two-step approach to sampling was used. Purposive sampling was used to select two large quintile 2 schools in the same township in Gauteng (Department of Basic Education, 2017). All schools in quintiles 1–3 are no-fee schools, so children attending them would be considered to be disadvantaged.

Selection of learners within the chosen schools

The participants were Grade 7 learners. Because of the limitations of IQ tests available in South Africa for black learners, an IQ test was not used for selection (Bouwer, 2014; Erasmos, 2013; Knowles, 2008; Maree, 2018; Mawila, 2012; Zygmont, 2006). Teacher identification could have been used, but giftedness is given little emphasis in teacher training in South Africa (Van der Westhuizen & Maree, 2006). Parent identification of the gifted is generally better than teacher identification (Dağlioğlu & Suveren, 2013; Gross, 1999). However, contact with parents in a quantitative study with large numbers of learners would have been impractical.

The study required that the learners have a sufficient grasp of the basic concepts of mathematics for their grade. It is impossible to access higher-level learning such as problem solving without a basic understanding of concepts (Johnson & Schmidt, 2006). Taking the issue of gifted identification together with the requirement for basic mastery of mathematical concepts, the learners' mathematics marks were used to identify mathematically gifted learners. Therefore, for the purposes of this study, the definition of mathematically gifted was the top 50 of the grade by mathematics year mark at the end of Grade 6. The top 50 equated to the top 14.1% of the grade at the intervention school (355 learners) and the top 14.7% of the grade at the alternative intervention school (340 learners).

Data-gathering instruments

The Study Orientation for Mathematics (SOM) (Maree et al., 2011) was used as the pre-test and post-test. The SOM is designed for Grades 7–12 learners (Maree et al., 2011). Advantages of the SOM include that it was normed on learners from different language and socio-economic groups in South Africa (Maree et al., 2009), reliability and validity are highly satisfactory (Maree et al., 2011), it is quick to administer, and can be administered by a teacher rather than a psychologist (Maree, 2020).

The sub-tests of the SOM for Grades 7–9 learners consist of study attitude, mathematics anxiety, study habits, problem-solving behaviour (PSB), and study milieu. Study attitude (14 questions) covers the feelings and attitudes that learners have towards mathematics. Mathematics anxiety (14 questions) covers the degree to which the learners exhibit anxious behaviours. Study habits (17 questions) refers to consistent study habits such as practicing examples, learning theorems and doing assigned work diligently. Problem-Solving Behaviour (18 questions) includes the act of self-reflection when approaching problem solving in mathematics. Study Milieu (13 questions) highlights the impact of the socio-economic situation and home language versus the language of learning on learners.

The SOM was normed on 3013 Grades 8–11 learners at high schools across South Africa, and the Grades 8 and 9 norms were extended for Grade 7 learners (Maree et al., 2011). The samples in the initial study by Maree et al. (2011) were chosen randomly on three levels: the education department of the learner (which until only a few years previously had been racially segregated, and so could be used as a proxy for race), language of instruction, and area (urban or rural). This sampling resulted in a spread of race and language groups reflecting the general high school population, including black learners from disadvantaged urban schools such as the participants in this study.

The reliability and validity of the SOM are high. In the original study by Maree et al. (2011), the reliability coefficients for the different fields for African language learners who did the test in English (the same demographic as the learners in our study) ranged from 0.67 to 0.77, with the overall reliability of all the fields together at 0.89. Table 1 in the results section shows the pre-test dataset compared with the African language norm group from the original study.

The authors of the SOM tried to ensure the content validity of the SOM by reviewing the literature on the subject, getting experts to check the ordering and wording of questions, checking the item field correlations, and checking with experts whether all the important aspects of each item were included (Maree et al., 2011).

In terms of construct validity, study attitude correlated with study habits; study attitude correlated with problem-solving behaviour; study habits correlated with problem-solving behaviour, and mathematics anxiety correlated with study milieu (Maree et al., 2011). In addition, there was a low correlation between two distinct groupings of items. study habits, study attitude, and problem-solving behaviour combine to measure 'academic behaviour in mathematics' and mathematics anxiety and study milieu combined to measure 'helplessness, anxiety and lack of control… in Mathematics' (Maree et al., 2011, p. 45).

TABLE 1: Reliability coefficients for the different fields for the pre-test compared with the Study Orientation in Mathematics African languages norm group.

Fields	SOM African languages norm (*N* = 955)	Study Pre-test (*N* = 67)
Study attitude	0.73	0.68
Mathematics anxiety	0.72	0.65
Study habits	0.77	0.73
PSB	0.67	0.78
Study Milieu	0.69	0.72
SOM total	**0.89**	**0.87**

Source: Adapted from Maree, J.G., Prinsloo, W.B.J., & Claassen, N.C.W. (2011). *Manual for the study orientation questionnaire in Maths (S.O.M.)* (p. 40). JvR Psychometrics
SOM, study orientation in mathematics; PSB, problem-solving behaviour.

To test concurrent validity, Maree et al. (2011) compared the SOM to two existing tests, the Diagnostic Tests in Mathematical Language (DTML) and the Achievement Test in Mathematics (ATM) and all the items except Problem-Solving Behaviour correlated at the 1% level. Maree et al. (2011) speculate that the lack of correlation in this sub-test is because of the questions in the DTML and the ATM not requiring problem-solving skills to answer successfully, which far from being a drawback of the SOM, shows its unique benefit.

A study of the SOM in relation to school mathematics results in the Northern Cape province of South Africa found that for:

> [*B*]oth genders and across all three race groups, the set of study orientation scales contributed significantly (at the 1% level) to the explanation of variance in mathematics achievement for Grade 9 learners. (Moodaley et al., 2006, p. 652)

These results show clear predictive validity for the SOM for white, black and so-called 'coloured' (mixed-race) learners in previously white schools.

Procedure

Intervention

The intervention consisted of 3 h-long facilitated sessions where the learners worked through past papers of the SA Mathematics Challenge for Grade 7 (SAMF, 2018). Because of the low problem-solving skills of mathematics teachers in South Africa (Chirove & Mogari, 2014; Govender, 2014b) and because of the success of Govender's (2014b) study of the SA Mathematics Challenge without overt teaching of problem-solving skills, facilitation was kept to a minimum. The three past papers covered the first-round papers from 2013, 2014, and 2018. Figure 2 shows examples of questions in the intervention and the alternative intervention.

Learners in the intervention group completed on average 42.07 questions during the study, of which they got 8.85 correct (21%). Learners were encouraged to work in pairs and to discuss their answers but were also allowed to work alone if they preferred. Over 90% of learners in the intervention group chose to work in pairs. Learners were also encouraged to take home the past papers to complete at home. Six learners did this after each of the first two sessions (participants 6, 9, 10, 11, 22, and 42 after session 1 and participants 6, 9, 10, 11, 18, and 19 after session 2), and two (participants 18 and 19) after the last session.

SA mathematics challenge intervention

10. The number 2A36B is a five-digit odd number which is divisible by 15. How many possible different values can A have?

10. Die getal 2A36B is 'n vyf-syfer onewe getal wat deelbaar is deur 15. Hoeveel verskillende moontlike waardes kan Ah ê?

(A) 6 (B) 5 (C) 4 (D) 3 (E) 2

11. Which number lies on the number line $\frac{1}{4}$ of the way from $\frac{1}{8}$ to $\frac{1}{4}$?

11. Watter getal lê op die getallelyn $\frac{1}{4}$ van die afstandvan $\frac{1}{8}$ na $\frac{1}{4}$?

(A) $\frac{1}{32}$ (B) $\frac{3}{16}$ (C) $\frac{5}{16}$ (D) $\frac{7}{48}$ (E) $\frac{5}{32}$

Alternative intervention

1. Use zero as the identity of addition, or one as the identity of multiplication to write a sum for the following:

		Zero as the identity addition	One as the identity of multiplication
a.	5	5 + 0 = 5	5 x 1 = 5
b.	7		
c.	9		
d.	100		
e.	34		
f.	2,5		
g.	0,1		

2. Use zero as the identity of addition, or one as the identity of multiplication to solve the following:

a. $b + 0 =$ ☐ b. d x ☐ $= d$ c. e x 1 = ☐

b x 1 = ☐ d + ☐ $= d$ $e + 0 =$ ☐

Source: Adapted from Department of Basic Education. (2018a). *Mathematics in English: Grade 7 book 1 terms 1 & 2* (8th ed.). Department of Basic Education and South African Mathematics Foundation. (2018). *Challenge questions & solutions*. South African Mathematics Foundation. Retrieved from https://www.samf.ac.za/en/sa-maths-challenge-past-question-papers-solutions

FIGURE 2: Example questions from SA Mathematics Challenge intervention and the alternative intervention.

After each session, the past papers were marked. However, to avoid emphasising scores rather than on the process of learning, these marks were not given to the learners. Instead, the following week, learners received an answer sheet printed from the SA Mathematics Challenge website, giving both the correct answer and a brief explanation. After the learners had been given the answer sheet, the primary researcher explained a selection of common mistakes.

Alternative intervention

The alternative intervention followed the same format as the intervention. Worksheets 1–6 from Mathematics in English Book 1: Grade 7 book 1 terms 1 and 2 (Department of Basic Education, 2018a) were used. Example questions are shown in Figure 2.

In contrast to the intervention group, fewer than 20% of the participants chose to work in pairs. Five learners took worksheets home after the first session and six after the second session, with three in common between the two sessions. There were far more questions in the alternative intervention worksheets than in the SA Mathematics Challenge worksheets because the questions were simple drill questions, rather than complex problem-solving questions. On average the participants in the alternative intervention completed 105.8 questions in total, compared with 42.07 in the SA Mathematics Challenge intervention. The average number of questions answered correctly was 87.23 (82%). Once again, after each session, the papers were marked, learners were given an answer sheet, and lastly, the primary researcher went over a few common errors on the board. The number of common errors was fewer than in the SA Mathematics Challenge intervention because the learners got fewer questions wrong than in the SA Mathematics Challenge past papers.

Ethical considerations

The ethics of this study were guided by the American Psychological Association's (APAs) five general principles: beneficence and non-maleficence; fidelity and responsibility; integrity; justice; and respect for people's rights (Elias & Theron, 2012). The study also conformed to the APA requirements for research, publication and assessment (American Psychological Association, 2017). Lastly, ethical clearance was required from the University of Pretoria and the Department of Basic Education, which included vetting of the study design and all letters sent to schools. Ethical clearance to conduct this study was obtained from the University of Pretoria Research Ethics Committee. (No. EP 18/06/01.

Rigour of the study

The study considered internal and external validity and reliability of the data. The following threats to internal validity were considered: history, maturation, instrumentation, testing, selection bias, mortality, contamination and treatment misidentification. To reduce the effect of history, the interventions ran just 13 days apart. Maturation was not a concern as the study was only 5 weeks in duration. The SOM is highly reliable (Maree et al., 2011) so instrumentation was not a problem. A testing disadvantage was that the pre- and post-tests were administered only 4 weeks apart, which could result in learners remembering what they answered the previous time, but this effect was assumed to be the same for both groups. Selection bias is usually countered by randomisation (Maree & Pietersen, 2016; Mertens, 2015). Because of the practicalities randomisation was not viable, so the schools were as closely matched as possible. In terms of mortality, there was a greater attrition rate at the intervention school than at the alternative intervention school. Contamination was avoided by not revealing to either school the other school taking part in the study. Also, although the schools were in the same overall area, they were not close to each other. Lastly, the primary researcher attempted to counter treatment misidentification by interacting with the alternative intervention group in the same manner as with the intervention group. The placebo effect applied to both groups, as participants, parents and teachers at both schools were aware of being chosen to participate in the study.

The factors influencing external validity include time, selection and setting (Creswell, 2014). As time passes, the results of the study could become less relevant. Because only two schools from the same area in Gauteng were selected for this study, it is not possible to generalise beyond this area, without replication of the study in other disadvantaged areas of the country. Lastly, as only one researcher was involved in the sessions, results may be bound by the setting. Only replication in other settings can counter this threat to external validity.

The reliability of quantitative data is the extent to which research findings or results from a test instrument can be replicated (Maree & Pietersen, 2016). As mentioned earlier, the reliability of the SOM has been established, and the reliability of the dataset for the study was examined in the data analysis.

Data analysis procedures

To check the reliability of the dataset from the study, Cronbach's alphas were calculated on the pre-test dataset (Tavakol & Dennick, 2011), which consisted of all the participants who completed both the pre- and post-test (27 from the intervention group and 40 from the alternative intervention group). The pre-test dataset was compared with the African language learners in the original sample used for norming the SOM. As can be seen from Table 1, the reliability of this study's sample compared well with the original sample. The PSB sub-test had a reliability of 0.78, which is above the acceptable cut-off of 0.7 (Muijs, 2004).

A demographic comparison was made of the two schools, comparing gender, age and home language. The Pearson's chi-square test on the cross-tabulation of gender by school showed that gender distribution did not differ significantly between the two schools (p-value = 0.34). In both schools, there were many more girls than boys in the top 50 in the grade. The age range was from 11 to 14 years in the intervention group, and 11 to 13 years in the alternative intervention group. The median age for both groups was

TABLE 2: Related-Samples Wilcoxon Signed Rank results showing differences between pre- and post-tests of the Study Orientation for Mathematics.

SOM Sub-test	Pre-mean	SD	Post-mean	SD	Standard test statistic	N	p	Effect size (r)
Intervention								
Study attitude	44.78	7.88	43.85	7.88	0.60	27	0.28	0.12
Mathematics anxiety	38.48	7.80	38.00	7.93	0.19	27	0.42	0.04
Study habits	47.85	9.43	46.85	9.93	0.42	27	0.34	0.08
PSB	46.48	12.70	44.67	11.28	0.81	27	0.21	0.16
Study milieu	38.74	7.66	38.14	6.23	0.25	27	0.40	0.05
SOM total	216.33	29.44	211.52	30.07	0.48	27	0.24	0.14
Alternative intervention								
Study attitude	44.70	7.29	44.95	6.68	0.31	40	0.38	0.05
Mathematics anxiety	39.53	7.85	40.92	8.20	1.17	40	0.12	0.18
Study habits	47.53	9.74	50.25	8.89	2.07	40	0.02*	0.33†
PSB	45.45	10.66	47.68	10.15	1.49	40	0.07	0.24†
Study milieu	37.13	7.92	38.08	7.51	0.74	40	0.23	0.12
SOM total	214.33	31.49	221.88	32.83	1.91	40	0.03*	0.30†

SOM, study orientation in mathematics; PSB, problem-solving behaviour; SD, standard deviation.

*, p significant at the 5% level or less.

†, $r > 60.2$ (small effect).

12.00 years; the mean for the intervention group was 12.30 years (s.d. = 10.9 months), and for the alternative intervention group was 12.08 years (SD = 7.4 months). Because age was not normally distributed, the non-parametric Mann–Whitney *U* test was used to analyse the data (Mat Roni et al., 2020; Pietersen & Maree, 2016). There was no significant difference between the two school samples in terms of age (*p*-value = 0.35). The number of home languages was extensive, with all 11 official languages, and 'other', represented between the two schools. There was some difference in terms of the spread of language groups at the two schools, with the intervention group having more learners from the Sotho–Tswana language group, and the alternative intervention having more Nguni language speakers, but both groups could be described as African language speakers taking the SOM in English.

The Mann–Whitney *U* test, which is a non-parametric test used in place of an independent *t*-test for small or non-normal samples (Pietersen & Maree, 2016), was used to compare the Grade 6 marks for the two schools. The sample from the intervention school had a much broader range of marks (51% to 90%) than that of the alternative intervention school (58% to 84%), and the median of the intervention group (72%) was considerably higher than the alternative intervention group (65%). The mean for the intervention group was 71.26% (SD = 10.97) and the mean for the alternative intervention group was 66.28% (SD = 6.46). The distribution of Grade 6 marks was not the same across schools (*p*-value = 0.04).

Furthermore, the pre-tests of the SOM for the two schools were compared. Descriptive statistics were computed across the two schools and then a non-parametric test (Mann–Whitney *U*) was performed. These tests aimed to find out if the schools could be considered to be equivalent in terms of problem-solving skills before the interventions. The *p*-values greater than 0.05 were obtained for all three tests, across all fields of the SOM. This shows that before the intervention, the two groups can be considered to be on par in terms of all sub-tests of the SOM, and in terms of overall mathematics study orientation.

Results and discussion of findings

The main null hypothesis for the study was: There is no significant difference between the pre-test and post-test mean scores for the two groups. To evaluate this hypothesis, the change in the score of the PSB sub-test of the SOM from the pre-test to the post-test in both schools was examined.

Comparing pre- to post-test

A Related-Samples Wilcoxon Signed Rank Test was chosen as a non-parametric test to investigate whether there was a significant change from the pre- to the post-test in the intervention group (Maree & Pietersen, 2016). Particular emphasis was placed on the results for the PSB sub-test of the SOM, as this was being used to assess whether the SA Mathematics Challenge intervention had improved the participants' problem-solving skills. The null hypothesis investigated was 'the median of differences between SOM PSB post-test and SOM PSB pre-test equals 0', with a one-sided alternative hypothesis. The median was chosen rather than the mean because the Wilcoxon Signed Rank Test, as a non-parametric test, utilises ordinal data (Mertens, 2015; Muijs, 2004). The significance of this test was 0.21, so there was no significant improvement in problem-solving skills from the SA Mathematics Challenge intervention, which was against expectations. There was also no significant improvement in problem-solving skills from the alternative intervention (*p*-value = 0.07).

The other sub-tests of the SOM were examined to see the impact of the interventions on the participants' study orientation in mathematics in general. As can be seen from Table 2, there was no significant change in study orientation after the intervention, with minimal effect sizes for all sub-tests, and there was a significant change in study habits and overall study orientation in Mathematics, with small effect sizes, after the alternative intervention.

To investigate whether low mathematics skills were a limit to developing problem-solving skills, the authors examined the top stratum of study participants. To do this, the authors went back to the original sample and took the top 5% (17 learners) in each school. Then, learners who did not complete both the sessions of the SOM were excluded, leaving a sample of 12 learners (2 boys and 10 girls) from the intervention school and 14 learners (2 boys and 12 girls) from the alternative intervention school. The lowest Grade 6 mark in this sample was 74% at the intervention school and 68% at the other school. The 5% sample was less affected by the dropout rate at the intervention school than the larger sample. However, neither the intervention nor the alternative intervention resulted in a significant difference in problem-solving skills. The *p*-value for the 5% group at the intervention school was 0.36 and the *p*-value for the 5% group at the alternative school was 0.17.

Discussion of results

Problem-solving behaviour

Studies of problem solving in mathematics vary in their approach on a continuum from overtly teaching problem-solving strategies to the pure experience of problem solving. This study was on the experiential end of the spectrum, with no overt teaching of strategies and learners were not asked to formally categorise their problem-solving methods. For the SA Mathematics Challenge group, there was a very slight decrease in PSB from the pre-test to the post-test, with a negligible effect size, as shown in Table 2. The participants also did not improve their average marks from the first to the third session of the SA Mathematics Challenge past papers, which contrasts with Govender's (2014b) study, where the in-service teachers improved their marks on the SA Mathematics Challenge after his intervention.

Problem-solving behaviour improved slightly from the pre- to the post-test for both the full alternative intervention group and the 5% sample. As can be seen in Table 2, there was a small effect size for the larger group and a negligible effect size for the 5% sample. This slight improvement in skills in a 3 h intervention correlates positively with the findings by Reder et al. (2020), Wang et al. (2017), and Gladwell (2008), who found that practice improves skills, but practice needs to be long term to have a significant effect.

Study attitude

Scores for the intervention group decreased slightly from the pre-test to the post-test, but the study attitude of the learners was still high, with participants scoring at the 80th percentile in study attitude compared with the Grades 8 and 9 norm group. The participants were above the 86th percentile of their class by mathematics achievement, so scoring at the 80th percentile is slightly less than expected. However, study attitude increases with age so these findings could be said to correlate with those of Maree et al. (2003, 2011) and Moodelay et al. (2006) that study attitude correlates positively with success in mathematics. In addition, as can be seen in Table 2, the learners in this study who were in the top 5% of the class scored higher in study attitude than those in the larger sample (top 14.1% of the class). This finding is also in line with the finding by Palomar-Lever and Victorio-Estrada (2017) that disadvantaged learners' attitude towards school correlates positively with achievement at school, and findings by Maree et al. (2003, 2011) and Moodelay et al. (2006) that Study Attitude correlates positively with achievement in mathematics.

Like with the intervention group, the study attitude scores were high both before and after the alternative intervention, which is in line with research that correlates academic success positively with study attitude (Goodman et al., 2011; Heuser & Wang, 2017; Maree et al., 2003, 2011; Moodaley et al., 2006; Palomar-Lever & Victorio-Estrada, 2017).

Mathematics anxiety

People are more likely to persist with a task if they believe they can succeed at it (Pajares, 1996). Anxiety interferes with this self-belief. In the SOM, a high score in the mathematics anxiety sub-test indicates high confidence in mathematical ability or low mathematics anxiety. The scores of the intervention group decreased slightly between the pre- and post-test, indicating a slight increase in anxiety levels, with a negligible effect size. The mean mathematics anxiety score for both the pre- and post-test was at the 60th percentile, which indicates quite high anxiety for learners who were above the 86th percentile in mathematics achievement. The vast majority of the participants in both interventions were girls, and the literature has shown that gifted girls tend to underestimate their mathematical ability (Pajares, 1996). This relatively high level of anxiety in high-performing students contradicts the findings of Hart et al. (2016) and Lindskog et al. (2017), who found that mathematics anxiety is inversely related to success in mathematics. Conversely, the mathematics anxiety scores support the findings that educationally disadvantaged high school and university students in a rural area all experienced mathematics anxiety to some degree (Hlalele, 2012, 2019).

The mean score on the mathematics anxiety sub-test of the SOM increased (i.e. indicating an improvement in confidence in mathematics) slightly for the intervention participants, with a negligible effect size, as can be seen in Table 2. This finding contrasts with Newstead (1998), who found that discovery teaching methods result in higher levels of mathematics confidence. The worksheet content was traditional, and although the way that it was presented to the learners with minimal input from a teacher could be described as experiential, it was less experiential than the SA Mathematics Challenge intervention, as most learners chose to work alone.

Study habits

Study habits have been correlated with academic success (Maree, 2015; Maree & Ebersöhn, 2002; Moodaley et al., 2006; Sikhwari, 2016). The SA Mathematics Challenge intervention did not result in improved study habits for the participants. Scores in Study Habits decreased slightly from the pre- to the post-test, with a negligible effect size. However, the participants in this study were somewhat younger than the norm group, and study habits increase with age (Maree et al., 2009). Taking the younger age of the participants in the study into account, these findings could be said to agree with the findings of Maree et al. (2011).

Table 2 shows that there was a statistically significant improvement in the study habits scores from the pre- to the post-test for the alternative intervention participants, with a small effect size. There was also an increase in the study habits score for the alternative intervention 5% sample, although it was not statistically significant, with a small effect size. Studies correlating study habits and success (Maree, 2015; Maree & Ebersöhn, 2002; Moodaley et al., 2006; Onoshakpokaiye, 2015; Sikhwari, 2016) are concerned with better study habits resulting in success, rather than the other way round. But, if the mathematical practice of routine worksheets improves study habits, it could be part of the reason why practicing mathematical skills in a structured way improves academic success, as has been shown by the Kumon method (Usmadi et al., 2020). The other reason would be practicing a particular algorithm to develop automaticity (Department of Basic Education, 2018b).

Study milieu

The mean study milieu score for both the intervention group and the alternative intervention group was higher than the 20th to 40th percentile that one would expect considering the socio-economic area where the school was situated (see Table 2). This contradicts the findings that poverty is directly related to the standard of education (Nortje, 2017) and that there is a positive relationship between both school resources and academic success (Lemmon, 2017; Letsoalo et al., 2019) and family resources and academic success (Gaillard, 2019; Uleanya & Bunmi Omoniyi, 2019). However, various factors have been shown to protect disadvantaged children from the poverty trap, namely being identified as gifted (Bolland et al., 2019); good child-rearing methods (Lipina, 2016), a positive relationship with a teacher; support from family or the community (Williams et al., 2017); a positive attitude to school (Palomar-Lever & Victorio-Estrada, 2017), and having a goal on which to focus (Kotzé & Niemann, 2013). The learners from this study had been identified as gifted by their selection to the study, had above-average scores in study attitude, and may have had some of the other protective factors despite the poverty of their community. Taking the protective factors into account, these findings could be said to be in line with both the findings that there is a positive relationship between resources and academic success (Gaillard, 2019; Lemmon, 2017; Letsoalo et al., 2019; Uleanya & Bunmi Omoniyi, 2019) and the findings on protective factors mitigating the effects of poverty (Bolland et al., 2019; Palomar-Lever & Victorio-Estrada, 2017).

Overall study orientation

Overall study orientation in mathematics predicts success in Mathematics (Maree et al., 2009; 2011; Moodaley et al., 2006), Engineering (Maree et al., 2003) and Natural sciences (Maree, 2015). The SA Mathematics Challenge intervention did not improve overall study orientation in the participants, but the alternative intervention resulted in a statistically significant improvement in overall study orientation, with a small effect size, that can be seen in Table 2. The improvement in the 5% sample of the alternative intervention was smaller, although starting from a higher base. The available studies on study orientation did not investigate improvement in study orientation brought about by an intervention, but these findings did concur with the prior findings that a positive study orientation in mathematics is correlated with academic achievement (Goodman et al., 2011; Maree et al., 2003, 2009, 2011; Moodaley et al., 2006; Palomar-Lever & Victorio-Estrada, 2017).

Integration of findings

Success in traditional mathematics

The study found a positive relationship between success in traditional mathematics and study attitude, study habits, and overall study orientation, in line with research on these aspects of study orientation (Heuser & Wang, 2017; Maree, 2015; Maree et al., 2003, 2011; Maree & Ebersöhn, 2002; Moodaley et al., 2006; Onoshakpokaiye, 2015; Palomar-Lever & Victorio-Estrada, 2017; Sikhwari, 2016).

The influence of poverty

The participants in this study were less disadvantaged by the poverty of their surroundings than would be expected, scoring at the 65th percentile in Study Milieu when their school was in a quintile 2 (20th to 40th percentile) area in terms of socio-economic status (SES). These study milieu scores contradict studies that show a positive relationship between study milieu and success in Mathematics (Gaillard, 2019; Lemmon, 2017; Letsoalo et al., 2019; Serrano Corkin et al., 2019; Uleanya & Bunmi Omoniyi, 2019; Van der Berg, 2015). However, these results are in line with studies that certain factors protect against poverty, including being identified as gifted (Bolland et al., 2019), study attitude (Palomar-Lever & Victorio-Estrada, 2017) and study habits (Kotzé & Niemann, 2013; Williams et al., 2017).

Problem solving

The study showed that Olympiad-type questions were more difficult for the participants than the alternative intervention. The finding that the SA Mathematics Challenge was difficult to the participants in this study was in line with other research into problem solving in South Africa (Engelbrecht & Mwambakana, 2016; Govender, 2014a; Mochesela, 2007) and abroad (Schoevers & Kroesbergen, 2017), and can be linked to findings that teachers in South Africa are themselves unfamiliar with problem solving and Olympiad-type questions (Govender, 2014b). Problem solving can be exacerbated by language difficulties (Mochesela, 2007; Sepeng, 2013; Sepeng & Webb, 2012; Tambychik & Meerah, 2010) so this angle of difficulty with problem solving would be worth investigating in future studies.

Strengths and limitations of the study

The strengths of this study were the selection of the schools and the use of the SOM for assessment. The two schools were well-matched in demographics as well as results on the pre-test of the SOM. The SOM was normed on disadvantaged South African learners and is a valid and reliable scientific instrument, which has been used in several studies in South Africa (Jagals, 2013; Molepo et al., 2005; Moodaley et al., 2006).

The limitations of the study were the sample size and area, the selection by Grade 6 marks, the short duration of the study, the lack of overt teaching and the relative difficulty of the interventions. Although the sample size was sufficient for statistical purposes, it was not large, and the two schools chosen were from the same township in Gauteng, so results cannot be generalised beyond the area where the study took place. Because of the difficulties of using IQ tests to assess disadvantaged learners and practical considerations, Grade 6 mathematics marks were used for selection. Additionally, the intervention took place at one school and the alternative intervention at the other, which precluded random assignment of participants to the intervention or alternative intervention group. The Grade 6 marks were not equivalent at the two schools and did not correlate with the SOM pre-test results. The study was very short, with no teaching of problem-solving skills. Overt skills building as offered by the Siyanqoba regional training for high school learners or the online SAMF Olympiad training for Grades 7–12 (SAMF, 2020a), in conjunction with practice of past papers, might have resulted in better skills acquisition. Lastly, the intervention and the alternative intervention were not equivalent in terms of difficulty.

Recommendations for future research

If this study were to be repeated, it is suggested that learners are not selected by marks, but rather by IQ test, the Grade 6 standardised Annual National Assessment (ANA) results or the PSB sub-test of the SOM. The reason for this is that this study showed that end-of-year marks are not comparable across schools.

Future repetitions of this study should include 10 or more sessions of SA Mathematics Challenge practice rather than just three. This would give learners a chance to self-develop skills over time. Additionally, overt teaching on how to approach various types of Mathematics Olympiad questions is recommended to scaffold the development of problem-solving skills in learners. Future researchers could analyse the success of the SAMF Olympiad training materials, other materials, or develop their own.

Lastly, it is recommended that schools in disadvantaged areas that are successful in the SA Mathematics Challenge are researched. Investigation of Olympiad preparation techniques used by no-fee schools that are successful in the SA Mathematics Challenge or Mathematics would potentially give a blueprint that could be rolled out to other no-fee schools. A comparative study of SOM PSB scores of learners at two disadvantaged schools, one that is successful in the SA Mathematics Challenge, and one that is not, could test the relationship between SOM PSB scores and success in the SA Mathematics Challenge.

Conclusion

This study found a positive relationship between success in traditional mathematics and study attitude, study habits, and overall study orientation. Poverty and giftedness were shown to interact: the gifted disadvantaged learners in this study were less disadvantaged by their surroundings than one would expect, and conversely had higher mathematics anxiety than expected for their achievement level.

More importantly, the study highlights that while opportunities for mathematically gifted learners in disadvantaged areas of South Africa do exist, much more could be done. The participants in this study found the problem-solving questions in the SA Mathematics Challenge difficult. Greater experience in Mathematics Olympiads, possibly coupled with teaching problem-solving techniques, may help mathematically gifted disadvantaged learners live up to their potential as South Africa's problem-solvers.

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Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

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Data availability

The data that support the findings of this study are available on request from the corresponding author, B.S. The data are not publicly available because of their content that could compromise the privacy of research participants.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. It does not necessarily reflect the official policy or position of any affiliated institution, funder, agency, or that of the publisher.

References

American Psychological Association. (2017). *Ethical principles of psychologists and code of conduct*. American Psychological Association.

Bolland, A.C., Besnoy, K.D., Tomek, S., & Bolland, J.M. (2019). The effects of academic giftedness and gender on developmental trajectories of hopelessness among students living in economically disadvantaged neighborhoods. *Gifted Child Quarterly*, *63*(4), 225–242. https://doi.org/10.1177/0016986219839205

Bouwer, L. (2014). *An improvement of the quality of the translated Sesotho Junior South African Individual Scale (GIQ-8) test items*. Master's thesis, University of Johannesburg, Johannesburg, South Africa. Retrieved from http://hdl.handle.net/10210/12240

Brown, J. (2016, August 26). Black middle class floating the economy. *City Press*. Retrieved from http://city-press.news24.com/Business/black-middle-class-floating-the-economy-20160826

Business Tech. (2016). *Black vs white middle class in South Africa*. Business Tech. Retrieved from https://businesstech.co.za/news/business/134749/black-vs-white-middle-class-in-south-africa/

Chetty, M. (2016). *Comparing school based assessments with standardised national assessments in South Africa*. Doctoral thesis, University of the Witwatersrand, Johannesburg, South Africa. Retrieved from http://hdl.handle.net/10539/20787

Chirove, M., & Mogari, D. (2014). Relationship between learners' mathematics-related belief systems and their approaches to non-routine mathematical problem solving: A case study of three high schools in Tshwane North District (D3), South Africa. In *2014 ISTE International Conference on Mathematics, Science and Technology Education*, *June* (pp. 119–130). Retrieved from http://hdl.handle.net/10500/22916

Christie, P., Butler, D., & Potterton, M. (2007). *Report to the Minister of Education: Ministerial committee on schools that work*. Retrieved from http://www.education.uct.ac.za/sites/default/files/image_tool/images/104/schoolsthatwork.pdf

Cockcroft, K. (2013). The senior South African individual scales – Revised: A review. In S. Laher & K. Cockcroft (Eds.), *Psychological assessment in South Africa: Research and applications* (pp. 48–59). Wits University Press.

Creswell, J.W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.

Cruickshank, J. (2011). The positive and the negative: Assessing critical realism and social constructionism as post-positivist approaches to empirical research in the social sciences. In International Migration Institute (Ed.), *The IMI Working Papers Series* (No. 42; IMI Working Papers Series, Issue August, pp. 1–20). International Migration Institute.

Dağlioğlu, H.E., & Suveren, S. (2013). The role of teacher and family opinions in identifying gifted kindergarten children and the consistence of these views with children's actual performance. *Kuram ve Uygulamada Egitim Bilimleri*, *13*(1), 444–453.

Department of Basic Education. (2017). *Quarter 4 of 2016: March 2017: Gauteng*. Schools Masterlist Data. Retrieved from https://www.education.gov.za/LinkClick.aspx?fileticket=E0TOnuayAFI%3D&tabid=466&portalid=0&mid=7070

Department of Basic Education. (2018a). *Mathematics in English: Grade 7 book 1 terms 1 & 2* (8th ed.). Department of Basic Education.

Department of Basic Education. (2018b). *Mathematics teaching and learning framework for South Africa: Teaching Mathematics for understanding*. Government printer.

Elias, M.J., & Theron, L.C. (2012). Linking purpose and ethics in thesis writing: South African illustrations of an international perspective. In J.G. Maree (Ed.), *Complete your thesis or dissertation successfully: Practical guidelines* (pp. 145–160). Juta.

Engel, R.J.E., & Shutt, R.K. (2014). *Fundamentals of social work research*. Sage.

Engelbrecht, J., & Mwambakana, J. (2016). Validity and diagnostic attributes of a mathematics olympiad for junior high school contestants. *African Journal of Research in Mathematics, Science and Technology Education*, *20*(2), 175–188. https://doi.org/10.1080/18117295.2016.1190211

Erasmos, C. (2013). *The impact of enrichment programs on the performance of gifted Science learners*. Master's thesis, University of South Africa, Pretoria, South Africa. Retrieved from http://hdl.handle.net/10500/14261

Erasmus, P. (2014). Assessment strategy in Mathematics for second language learners. *Literacy Information and Computer Education Journal*, *5*(4), 1655–1660. https://doi.org/10.20533/licej.2040.2589.2014.0221

Gaillard, C. (2019). Finding the missing variables: A systematic review of mathematics improvement strategies for South African public schools. *South African Journal of Education*, *39*(3), 1–9. https://doi.org/10.15700/saje.v39n3a1582

Gladwell, M. (2008). *Outliers*. Penguin Books.

Goodman, S., Jaffer, T., Keresztesi, M., Mamdani, F., Mokgatle, D., Musariri, M., Pires, J., & Schlechter, A. (2011). An investigation of the relationship between students' motivation and academic performance as mediated by effort. *South African Journal of Psychology*, *41*(3), 373–385. https://doi.org/10.1177/008124631104100311

Govender, V.G. (2014a). Factors contributing to the popularity of Mathematics Olympiads and competitions in some schools: An interrogation of learners' and teachers' views. In M. Lebitso & A. Maclean (Eds.), *20th Annual National Congress of the Association for Mathematics of South Africa* (pp. 70–86). AMESA. Retrieved from http://www.amesa.org.za/AMESA2014/Proceedings/index.html

Govender, V.G. (2014b). Using the South African mathematics challenge to develop pre-service mathematics teachers' problem-solving abilities. In M. Lebitso & A. Maclean (Eds.), *20th Annual National Congress of the Association for Mathematics of South Africa* (pp. 87–104). AMESA. Retrieved from http://www.amesa.org.za/AMESA2014/Proceedings/index.html

Griesel, H., & Parker, B. (2009). *Graduate attributes: A baseline study on South African graduates from the perspective of employers*. Higher Education South Africa & the South African Qualifications Authority.

Grønmo, L.S., Lindquist, M., Arora, A., & Mullis, I.V.S. (2013). TIMSS 2015 Mathematics framework. In I. Mullis & M. Martin (Eds.), *TIMSS 2015 assessment frameworks* (pp. 11–27). TIMSS & PIRLS International Study Center, Boston College.

Gross, M.U.M. (1999). Small poppies: Highly gifted children in the early years. *Roeper Review*, *21*(3), 207–214.

Hart, S.A., Logan, J.A.R., Thompson, L., Kovas, Y., McLoughlin, G., & Petrill, S.A. (2016). A latent profile analysis of math achievement, numerosity, and math anxiety in twins. *Journal of Educational Psychology*, *108*(2), 181–193. https://doi.org/10.1037/edu0000045

Health Professions Council of South Africa. (2017). Tests that have been classified and reviewed. Retrieved from Government Gazette website: https://www.hpcsa.co.za/Uploads/PSB_2019/List_of_Classified_tests_Board_Notice_155_of_2017.pdf

Heuser, B.L., & Wang, K. (2017). Global dimensions of gifted and talented education: The influence of national perceptions on policies and practices. *Global Education Review*, *4*(1), 4–21.

Hlalele, D. (2012). Exploring rural high school learners' experience of Mathematics anxiety in academic settings. *South African Journal of Education*, *32*(3), 267–278. https://doi.org/10.15700/saje.v32n3a623

Hlalele, D. (2019). Exploring rural university access programme students' experience of Mathematics anxiety in academic settings. *Africa Education Review*, *16*(1), 40–57. https://doi.org/10.1080/18146627.2016.1224580

Israel, N. (2006). *Raven's Advanced progressive matrices within a South African context*. Master's thesis, University of the Witwatersrand, Johannesburg, South Africa. Retrieved from http://hdl.handle.net/10539/1703

Jagals, D. (2013). *An exploration of reflection and Mathematics confidence during problem solving in senior phase Mathematics*. Master's thesis, North-West University, Potchefstroom, South Africa. Retrieved from http://hdl.handle.net/10394/9067

Jordan, S.-C. (2015). *The languages of South Africa*. Retrieved from https://alphaomegatranslations.com/foreign-language/the-languages-of-south-africa/

Knowles, J. (2008). *Assessment of non-verbal intelligence in South African schools: Do language and gender bias performance on the Raven's Standard progressive matrices?*. Master's thesis, University of the Witwatersrand, Johannesburg, South Africa. Retrieved from http://hdl.handle.net/10539/8238

Kotzé, M., & Niemann, R. (2013). Psychological resources as predictors of academic performance of first-year students in higher education. *Acta Academica*, *45*(2), 85–121.

Laubscher, L., & Olszewski-Kubilius, P. (1996). The impact of a college counseling program on economically disadvantaged gifted students and their subsequent college adjustment. *Roeper Review*, *18*(3), 202–208. https://doi.org/10.1080/02783199609553735

Lemmon, D.K. (2017). *An outcome evaluation of the Centre of Science and Technology*. Master's thesis, University of Cape Town, Cape Town, South Africa. Retrieved from http://hdl.handle.net/11427/25363.

Letsoalo, M.E., Masha, J.K., & Maoto, R.S. (2019). The overall performance of Grade 12 Mathematics and Physical Science learners in South Africa's Gauteng province. *Journal of Gender, Information and Development in Africa, 8*(1), 9–42. https://doi.org/10.31920/2050-4284/2019/8n1a1

Lindskog, M., Winman, A., & Poom, L. (2017). Individual differences in nonverbal number skills predict Math anxiety. *Cognition*, *159*, 156–162. https://doi.org/10.1016/j.cognition.2016.11.014

Lipina, S.J. (2016). The biological side of social determinants: Neural costs of childhood poverty. *Prospects*, *46*(2), 265–280. https://doi.org/10.1007/s11125-017-9390-0

Lohman, D.F., Korb, K.A., & Lakin, J.M. (2008). Identifying academically gifted English-language learners using nonverbal tests: A comparison of the Raven, NNAT, and CogAT. *Gifted Child Quarterly, 52*(4), 275–296. https://doi.org/10.1177/0016986208321808

Long, C., & Wendt, H. (2017). A comparative investigation of South Africa's high-performing learners on selected TIMSS items comprising multiplicative concepts. *African Journal of Research in Mathematics, Science and Technology Education, 1*(2), 1–8. https://doi.org/10.1080/02699931.2011.628301

Lubinski, D., & Benbow, C.P. (2006). Special section: Doing psychological science study of mathematically precocious youth after 35 years. *Perspectives on Psychological Science, 1*(4), 316–345. https://doi.org/10.1111/j.1745-6916.2006.00019.x

Maree, J.G. (2015). Barriers to access to and success in higher education: Intervention guidelines. *South African Journal of Higher Education, 29*(1), 390–411.

Maree, J.G. (2018). Gifted education in Africa. In S.I. Pfeiffer, E. Shaunessy-Dedrick & Megan Foley-Nicpon (Eds.), *APA handbook of giftedness and talent* (1st ed.). American Psychological Association.

Maree, J. G. (2020). *Study orientation in Mathematics*. Retrieved from https://jvrafricagroup.co.za/catalogue/som

Maree, J.G., & Ebersöhn, L. (2002). Emotional intelligence and achievement: Redefining giftedness? *Gifted Education International, 16*(3), 261–273. https://doi.org/10.1177/026142940201600309

Maree, J.G., & Erasmus, C.P. (2006). Mathematics skills of Tswana-speaking learners in the North West Province of South Africa. *Early Child Development and Care, 176*(1), 1–18. https://doi.org/10.1080/03004430500209696

Maree, J.G., & Pietersen, J. (2020). The quantitative research process. In K. Maree (Ed.), *First steps in research* (3rd ed., pp. 184–195). Van Schaik Publishers.

Maree, J.G., Pretorius, A., & Eiselen, R.J. (2003). Predicting success among first-year engineering students at the Rand Afrikaans University. *Psychological Reports, 93*(2), 399–409. https://doi.org/10.2466/pr0.2003.93.2.399

Maree, J.G., Prinsloo, W.B.J., & Claassen, N.C.W. (2011). *Manual for the study orientation questionnaire in Maths (S.O.M.)*. JvR Psychometrics.

Maree, J.G., van der Walt, M.S., & Ellis, S.M. (2020). *TriMaths*. Retrieved from https://jvrafricagroup.co.za/catalogue/tri-maths

Maree, J.G., Van der Walt, M.S., & Ellis, S.M. (2009). Developing a study orientation questionnaire in Mathematics for primary school students. *Psychological Reports, 104*(2), 425–438. https://doi.org/10.2466/PR0.104.2.425-438

Maree, K. (2016). Planning a research proposal. In K. Maree (Ed.), *First steps in research* (2nd ed.). Van Schaik.

Maree, K., & Pietersen, J. (2016). The quantitative research process. In K. Maree (Ed.), *First steps in research* (2nd ed., pp. 162–170). Van Schaik.

Mat Roni, S., Merga, M.K., & Morris, J.E. (2020). *Conducting quantitative research in education*. Springer Nature Singapore.

Mawila, D. (2012). *An explorative investigation of the quality of items of the performance scales on the translated Sesotho version of the Junior South African Individual Scales JSAIS (GIQ-8)*. Master's thesis, University of Johannesburg, Johannesburg, South Africa. Retrieved from http://hdl.handle.net/10210/8695

Mayaba, P.L. (2016). *The cultural and linguistic appropriateness of the Individual Scale for Zulu-speaking pupils: A Bakhtinian analysis*. Doctoral thesis, University of KwaZulu-Natal, South Africa. Retrieved from http://hdl.handle.net/10413/14903

Mertens, D.M. (2015). *Research and evaluation in education and psychology* (4th ed.). Sage.

Mhlolo, M.K. (2011). *From coherence in theory to coherence in practice: A stock-take of the written, tested and taught National Curriculum Statement for Mathematics (NCSM) at Further Education and Training (FET) level in South Africa*. Doctoral thesis, University of the Witwatersrand, Johannesburg, South Africa. Retrieved from http://hdl.handle.net/10539/11274

Mhlolo, M.K. (2015). Examining covert impediments to inclusive education for the mathematically gifted learners in South Africa. In F.M. Singer, F. Toader & C. Voica (Eds.), *9th International Mathematical Creativity & Giftedness (MCG) Conference* (pp. 166–171). The International Group for Mathematical Creativity and Giftedness. Retrieved from http://www.mcg-9.net/

Mochesela, P.R. (2007). *The role of the problem-based approach in the performance of Grade 9 learners in solving word problems*. Master's thesis, University of South Africa, Pretoria, South Africa. Retrieved from http://hdl.handle.net/10500/559

Modisaotsile, B.M. (2012). The failing standard of Basic Education in South Africa. Institute of South Africa (AISA). *Policy brief Number* 72, March 2012.

Mohlala, S.C. (2000). *The identification of gifted children in an under-resourced rural area*. Master's thesis, University of South Africa, Pretoria, South Africa. Retrieved from http://hdl.handle.net/10500/17476

Molepo, J., Owen, J., Ehlers, R., & Maree, J. (2005). Probleemgebaseerde benadering tot wiskunde in graad 9 en 11 in die Limpopo-provinsie [Problem-based approach to mathematics in Grade 9 and Grade 11 in the Limpopo Province]. *SA Tydskrif Vir Natuurwetenskap En Tegnologie, 24*(4), 124–133. https://doi.org/10.4102/satnt.v24i4.181

Moodaley, R.R., Grobler, A.A., & Lens, W. (2006). Study orientation and causal attribution in Mathematics achievement. *South African Journal of Psychology, 36*(3), 634–655. https://doi.org/10.1177/008124630603600312

Muijs, D. (2004). *Doing quantitative research in education with SPSS*. Sage.

Mullis, I.V.S., Martin, M.O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in Mathematics*. IEA.

Murray, M. (2017). How does the grade obtained at school for English and Mathematics affect the probability of graduation at a university? *Pythagoras, 38*(1), 1–7. https://doi.org/10.4102/pythagoras.v38i1.335

Newstead, K. (1998). Aspects of children's Mathematics anxiety. *Educational Studies in Mathematics, 36*(1), 53–71. https://doi.org/10.1023/A:1003177809664

Nieuwoudt, S. (2015). Developing a model for problem-solving in a Grade 4 Mathematics classroom. *Pythagoras, 36*(2), 1–7. https://doi.org/10.4102/pythagoras.v36i2.275

Nortje, J.M. (2017). The effect of poverty on education in South Africa. *Educor Multidisciplinary Journal, 1*(December), 47–62.

Onoshakpokaiye, E.O. (2015). Relationship of study habits with Mathematics achievement. *Journal of Education and Practice, 6*(10), 168–171.

Pajares, F. (1996). Self-efficacy beliefs and mathematical problem-solving of gifted students. *Contemporary Educational Psychology, 21*(4), 325–344. https://doi.org/10.1006/ceps.1996.0025

Palomar-Lever, J., & Victorio-Estrada, A. (2017). Academic success of adolescents in poverty. *Social Psychology of Education, 20*(3), 669–691. https://doi.org/10.1007/s11218-017-9389-7

Pietersen, J., & Maree, K. (2016). Overview of some of the most popular statistical techniques. In K. Maree (Ed.), *First steps in research* (2nd ed., pp. 249–304). Van Schaik.

Reder, S., Gauly, B., & Lechner, C. (2020). Practice makes perfect: Practice engagement theory and the development of adult literacy and numeracy proficiency. *International Review of Education, 66*(2–3), 267–288. https://doi.org/10.1007/s11159-020-09830-5

Rindermann, H., Sailer, M., & Thompson, J. (2009). The impact of smart fractions, cognitive ability of politicians and average competence of peoples on social development. *Talent Development and Excellence, 1*(1), 3–25.

Schoevers, E.M., & Kroesbergen, E.H. (2017). Enhancing creative problem solving in an integrated visual art and geometry program: A pilot study. In D. Pitta-Pantazi (Ed.), *The 10th Mathematical creativity and giftedness International Conference* (pp. 27–32). Department of Education, University of Cyprus.

Sepeng, P. (2013). Exploring issues of the use of language as a pedagogical tool in the learning of mathematics. In UNISA (Ed.), *2013 ISTE International Conference on Mathematics, Science and Technology Education* (pp. 123–132). UNISA Press.

Sepeng, P., & Webb, P. (2012). Exploring mathematical discussion in word problem-solving. *Pythagoras, 33*(1), 1–8. https://doi.org/10.4102/pythagoras.v33i1.60

Serrano Corkin, D., Coleman, S.L., & Ekmekci, A. (2019). Navigating the challenges of student-centered Mathematics teaching in an urban context. *Urban Review, 51*(3), 370–403. https://doi.org/10.1007/s11256-018-0485-6

Shuttleworth-Edwards, A.B., Garland, E.K., & Radloff, S.E.R. (2013). WAIS-III test performance in the South African context: Extension of a prior cross-cultural normative database. In S. Laher & K. Cockcroft (Eds.), *Psychological assessment in South Africa: Research and applications* (pp. 17–32). Wits University Press.

Sikhwari, T.D. (2016). Study habits, attitudes and academic achievement: Comparing Grade 12 learners between two secondary schools. *Journal of Educational Studies, 15*(2), 43–61.

South African Market Insights. (2020). *South Africa's education statistics*. South African Market Insights. Retrieved from https://www.southafricanmi.com/education-statistics.html

South African Mathematics Foundation. (2018). *Challenge questions & solutions*. South African Mathematics Foundation. Retrieved from https://www.samf.ac.za/en/sa-maths-challenge-past-question-papers-solutions

South African Mathematics Foundation. (2020a). *Learner development*. South African Mathematics Foundation. Retrieved from https://www.samf.ac.za/en/mathematics-learner-development.

South African Mathematics Foundation. (2020b). *South African Mathematics Challenge*. South African Mathematics Foundation. Retrieved from http://www.samf.ac.za/en/sa-mathematics-challenge

Statistics South Africa. (2017). Poverty trends in South Africa: *An examination of absolute poverty between 2006 and 2015*. Statistics South Africa. Retrieved from https://www.statssa.gov.za/?page_id=1854&PPN=Report-03-10-06

Stones, R.A. (2020). *South African Mathematics challenge participation: Developing problem-solving skills in mathematically-gifted disadvantaged learners*. Master's thesis, University of Pretoria, Pretoria, South Africa.

Tambychik, T. & Meerah, T.S.M. (2010). Students' difficulties in mathematics problem-solving: What do they say? *Procedia - Social and Behavioral Sciences, 8*, 142–151. https://doi.org/10.1016/j.sbspro.2010.12.020

Te Nijenhuis, J., Murphy, R., & Van Eeden, R. (2011). The Flynn effect in South Africa. *Intelligence, 39*(6), 456–467. https://doi.org/10.1016/j.intell.2011.08.003

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Uleanya, C., & Bunmi Omoniyi, I. (2019). Effects of household poverty trap on learners' academic performances: A case of rural high schools in Nongoma Circuit of South Africa. *Affrika: Journal of Politics, Economics and Society, 9*(1), 139–165. https://doi.org/10.31920/2075-6534/2019/9n1a7

University of Cape Town. (2019). *UCT Mathematics competition*. University of Cape Town. Retrieved from http://www.uctmathscompetition.org.za/

University of Pretoria. (2019). *UP Mathematics competition*. University of Pretoria. Retrieved from https://www.up.ac.za/mathematics-and-applied-mathematics/article/47663/up-mathematics-competition

University of Witwatersrand. (2019). *Wits Mathematics competition*. Retrieved from http://wmc.ms.wits.ac.za/.

Usmadi, Agita, A., & Ergusni. (2020). The effect of application Kumon Learning method in learning Mathematics of ability troubleshooting Mathematics of students. *Journal of Physics: Conference Series, 1429*(1). https://doi.org/10.1088/1742-6596/1429/1/012005

Van Broekhuizen, H., Van der Berg, S., & Hofmeyr, H. (2016). *Higher education access and outcomes for the 2008 National Matric Cohort*. Stellenbosch Economic Working Papers No.16/2016.

Van der Berg, S. (2015). What the Annual National Assessments can tell us about learning deficits over the education system and the school career. *South African Journal of Childhood Education, 5*(2), 16. https://doi.org/10.4102/sajce.v5i2.389

Van der Westhuizen, C. (2007). Undervalued and under-served: The gifted disadvantaged. *Gifted Education International, 23*(2), 138–148.

Van Eeden, R. (1991). *Manual for the Senior South African Individual Scale — Revised (SSAIS-R)*. Human Sciences Research Council.

Venkat, H., & Spaull, N. (2015). What do we know about primary teachers' mathematical content knowledge in South Africa? An analysis of SACMEQ 2007. *International Journal of Educational Development, 41*, 121–130. https://doi.org/10.1016/j.ijedudev.2015.02.002

Wang, C., Weng, J., Yao, Y., Dong, S., Liu, Y., & Chen, F. (2017). Effect of abacus training on executive function development and underlying neural correlates in Chinese children. *Human Brain Mapping, 38*(10), 5234–5249. https://doi.org/10.1002/hbm.23728

Williams, J.M., Bryan, J., Morrison, S., & Scott, T.R. (2017). Protective factors and processes contributing to the academic success of students living in poverty: Implications for counselors. *Journal of Multicultural Counseling and Development, 45*(3), 183–200. https://doi.org/10.1002/jmcd.12073

Zygmont, C.S. (2006). *An exploratory factor analysis of the Junior South African Individual Scales (JSAIS)*. Master's thesis, Stellenbosch University, Stellenbosch, South Africa. Retrieved from http://hdl.handle.net/20.500.11892/31920