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The predictive value of study orientations on mathematics performance in South African Grade 9 learners

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Mathematics achievement is core to South Africa's readiness for digital innovation, yet current pass rates in this subject are below the global average. Simply attributing mathematics performance to intelligence does not fully account for the multifaceted reality of achievement in the subject. The current study investigated the value of both cognitive and behavioural factors in predicting mathematics performance, as well as explored the interactions between these factors. A quantitative, cross-sectional design was employed. Grade 9 learners (N = 187) completed the Ravens' Standard Progressive Matrices and the Study Orientation towards Mathematics assessments to establish their fluid intelligence, study attitude, mathematics anxiety, study habits, problem-solving behaviours and study milieu. Pearson correlation coefficients established the relationships between fluid intelligence, study orientations towards mathematics, and mathematics marks. These factors were also included in a linear regression and dominance analysis to compare their relative weights in influencing mathematics performance. Study attitude and fluid intelligence were found to be the most dominant, significant factors in the model, which explained 39% of the total variance ($R^2 = 0.390$, $F(6, 180)$, = 19.2, $p < 0.001$). Moderator regressions between fluid intelligence and each of the study orientations further found that fluid intelligence and study orientations, with the exception of study milieu, independently influence mathematics performance.

Contribution: This study proposes that educators and parents should support curriculum change that encourages positive attitudes towards mathematics and create supportive environments conducive to effective learning, rather than blaming a lack of cognitive potential for the disappointing mathematics pass rate.

Keywords: Mathematics performance; fluid intelligence; attitudes; anxiety; habits; problem-solving behaviour; milieu

Introduction

It is essential to empower young people with the competence to achieve in mathematics, especially if South Africa wants to position itself as a leader in areas such as artificial intelligence, robotics, genetics, and digital innovations (Baller et al., 2016). With this in mind, South Africa had set the goal of enabling approximately 90% of Grade 9 learners to achieve 50% or more in their annual national mathematics assessments over a decade ago (National Development Plan [NDP] 2030, 2012).

Current realities, however, do not align with these visionary goals as the quality of South African mathematics education is on par with that associated with a low-income country, rather than that of a middle-income nation (Van der Berg et al., 2020). Reports on the 2023 National Senior Certificate (NSC) Examinations outcomes reveal a national mathematics pass rate of 63.5%, a significant 8.5% improvement from the 55.0% achieved in 2022. However, a 2.9% decline in mathematics enrollments was noted in 2023, after a 3.9% increase in 2022. Further examination of these pass rates shows that only 3.4% of learners who wrote Mathematics passed with distinction (a mark of 80% or higher), while only 2.2% of learners who completed the Mathematics Literacy paper passed with distinction (Mweli, 2023). With under 5% of the Matric group of 2023 having achieved above 80% in their final mathematics examination, these rates are concerning for South Africa's future as a digital leader.

Attributing mathematics performance to a single factor, such as higher innate intelligence or teaching efficiency, neither motivates nor encourages learners to exhibit any effort nor reflects the multifaceted complexity of mathematical learning (Harris, 2018). In contrast to intelligence, which is considered as considerably stable across the lifespan, study orientations are malleable in that learners can adjust their approaches, motivations, study methods, and attitudes towards mathematics (Maree et al., 2011). While O'Hara et al. (2022) underline the importance of a supportive classroom learning environment in mitigating mathematics anxiety, Cheema and Sheridan (2015) found that positive habits such as spending sufficient time studying mathematics can mitigate the influence of mathematics anxiety on mathematics performance, even when accounting for learner socioeconomic status. In promoting positive study habits, many learners will grow in confidence in their mathematics abilities, thereby motivating them to persist with difficult material despite possible fears of failure (Özcan & Gümüs, 2019). Therefore, to appreciate the variability in factors that underlie mathematics performance in high school learners, this study's value lies in evaluating the dynamic interplay between intellectual and behavioural factors. By understanding these interactions between cognition and study orientations, educators can take a more focused approach when developing interventions aimed at enhancing mathematics performance.

Conceptual framework

It has been established that cognitive ability, reflective of a person's intellectual potential, is a key determinant of mathematics performance (Abin et al., 2020). Piaget (1928; 1960), an early theorist who studied cognitive development in children, proposed that children constructed cognitive development by moving through four sequential and universal development stages. These four stages consisted of: (1) sensorimotor stage, from birth to 2 years of age, (2) preoperational stage, ages 2 to 7 years, (3) concrete operational stage, ages 7 to 11 years, and (4) formal operational stage, ages 11 years and older. The key attainments during the formal operational stage are that, first, adolescents' problem-solving processes commence with a hypothesis or prediction where inferences can logically be deduced and confirmed (Inhelder & Piaget, 1958). Second, these inferences can be evaluated without reference to real-world circumstances (Inhelder & Piaget, 1958), creating cognitive capacity for abstract and systematic thought processes which are required of learners from Grades 7 to 9 and onwards. In this study, it is therefore assumed that South African Grade 9 learners, between the ages of 14 and 16 years, are functioning at this formal operational development stage.

However, Piaget's stages have been countered by studies that found that cognitive development is a constant acquisition and modification of thought process throughout childhood and adolescence (Bjorklund, 2012). Abstract reasoning has also been found to develop as an individual receives extensive exposure, guidance, and practice in the use thereof (Kuhn, 2008), contradicting Piaget's acceptance that the formal operational stage is invariant and occurs naturally once an individual's prefrontal cortex matures. In this regard, Bolton and Hattie (2017) noted that the relationship between genetics and the development of executive functioning, performed by the prefrontal cortex and which includes skills such as planning and adaptive thinking, had yet to be determined. Therefore, Bolton and Hattie suggest that children may not develop the required biological structures at the same rate and within the provided age brackets to fit into the proposed four-stage theory of Piaget (1928). Nevertheless, Piaget's constructive vision of a child's cognitive development laid the general foundation for the current study. The Piagetian 'milestone' approach adds valuable insights when the South African context is considered, where there are still notable disparities in socioeconomic conditions and quality of education (Department of Basic Education, 2019). Subject curricula are based on the principle of progression, which includes empowering learners to acquire specific skills, develop understanding, and competently apply these skills. However, drawing parallels with elements of Piaget's theory, the quality of the exposure of these skills and how confidence is developed depends on the social resources available.

Given the diverse context of South Africa – with multilingualism and inequalities in education opportunities – assessing intelligence fairly is often challenging. Crystallised intelligence can be acquired and learnt, and is therefore influenced by environmental, cultural and social factors (Brown, 2016). In contrast, fluid intelligence relates to 'raw' intelligence that individuals possess, relating to information processing, working memory, and the ability to establish relationships between concepts, without educational influences. Floyd et al. (2003) highlighted that fluid intelligence assessments measure patterns of thinking that are transferrable to mathematics performance, tapping into elements of problem-solving and strategic, abstract thinking. Geary et al. (2019) noted that both fluid and crystallised intelligence contributed to the mathematics performance of adolescents; however, the ability to grasp and understand the novel concepts that are continuously introduced is related solely to fluid intelligence. Cormier et al. (2017) therefore argue that across age and ethnic groups, fluid intelligence is the better cognitive predictor of mathematics achievement. However, given the relative stability of intelligence across the lifespan, other constructs should also be considered given the multifaceted nature of mathematics performance.

Non-cognitive aspects, such as planning and organisation abilities, self-discipline, self-concept, learning routines and habits, stress management, test anxiety and motivation have consistently been found to have an impact on academic performance (Wehner & Schils, 2021). In this regard, study orientations are malleable behaviours in that learners can adjust their approaches, motivations, study methods, and attitudes towards mathematics (Maree et al., 2014). Maree et al. (2014) also recommend that intervention strategies aimed at study orientations to mathematics could help remedy the national problem around mathematics education. However, South African research on study orientations is limited (Erasmus, 2013; Morse, 2022), with no known research to date investigating the contribution of study orientations towards mathematics on mathematics performance while accounting for cognitive potential. Maree et al. identified six distinct study orientation factors that significantly influence mathematics performance: (1) study attitude, (2) mathematics anxiety, (3) study habits, (4) problem-solving behaviours, (5) study milieu, and (6) information processing. Information processing is a concept most relevant to the Grade 10–12 syllabus since it relates mostly to the application and conceptualisation of mathematical theory, and will therefore not be discussed further since it is not relevant to the current study or sample of learners. The five study orientations investigated in this study will now be discussed further.

Study attitude relates to one's self-confidence, enjoyment and belief that mathematics is useful, which in turn has an impact on one's motivation and interest towards the subject. Following Mabena et al. (2021) noting disinterest towards mathematics as a contributor to more South African learners choosing Mathematics Literacy over Mathematics, evaluating the predictive value of this construct is key to encouraging teachers, parents and learners alike to endeavour to make mathematics classes and homework activities interesting.

Mathematics anxiety is operationally defined as the panic, anxiety, and concern that presents as aimless and repetitive behaviours such as nail-biting, scrapping of correct answers, and inability to speak clearly (Maree et al., 2014). Although increased levels of mathematics anxiety have been found to negatively impact mathematics performance across ages (Zhang et al., 2019), the extent of this anxiety and how it affects learning and achievement depends on learners' abilities, stress responses, and emotional stability (Wehner & Schils, 2021).

Study habits are defined as a learner's willingness to focus on learning mathematics by consistently working through homework, assignments and past tests and examination papers. Acido (2010) found that individuals with below-average reasoning ability had poorer study habits compared to their peers with above-average reasoning. Positive study attitudes also makes it easier to implement regular study habits (Akben-Selcuk, 2017), and effective study habits in turn reduce test anxiety while improving achievement motivation (Tuncay, 2011).

Problem-solving behaviour refers to the underlying cognitive and meta-cognitive learning strategies, such as planning strategies, appraising and approximating, and inferring when solving mathematical problems. Erickson and Heit (2015) found that high schoolers often expressed overconfidence in their mathematics-related metacognition, despite experiencing high levels of mathematics anxiety, which likely resulted in them underpreparing for mathematics activities. In addition, Baten and Desoete (2019) found that metacognition was a significant predictor of mathematics accuracy.

Study milieu encompasses the sociocultural and physical environments that learners are exposed to when growing up, including both home and school settings. In support of the impact of social milieu on mathematics performance, Hu et al. (2018) found that after controlling for socioeconomic status, national GDP per capita, and gender, national culture accounted for 23.9% of country differences in mathematics achievement. However, the Organisation for Economic Cooperation and Development (2019) highlight that although social disadvantage does contribute to poor educational performance in 15-year-olds, the value of motivation, resilience, parental support, and a positive school environment should not be underestimated.

Aim and objectives

The overall aim of the present study is to determine the predictive value of fluid intelligence and study orientations in a South African Grade 9 sample. In determining each factor's value, the study is answering the research question of whether mathematics performance can largely be attributed to fluid intelligence, or whether behavioural influences, such as study orientations, also impact observed mathematics performance. These results have theoretical implications for future studies across the country as well as internationally, and also allow for practical suggestions to be shared within the education communities and possibly support curriculum change, allowing for a more focused approach to this national concern.

Following from this aim, the key objectives of this study are to:

- Determine the relative dominance weighting of fluid intelligence and each study orientation factor in predicting mathematics performance.
- Evaluate the moderating interactions between fluid intelligence and each study orientation factor in predicting mathematics performance.

Objective two was further investigated by a number of hypotheses:

H_O1: Study attitude does not moderate the relationship between fluid intelligence and mathematics performance.

H_A1: Study attitude moderates the relationship between fluid intelligence and mathematics performance.

H_O2: Mathematics anxiety does not moderate the relationship between fluid intelligence and mathematics performance.

H_A2: Mathematics anxiety moderates the relationship between fluid intelligence and mathematics performance.

H_O3: Study habits do not moderate the relationship between fluid intelligence and mathematics performance.

H_A3: Study habits moderate the relationship between fluid intelligence and mathematics performance.

H_O4: Problem-solving behaviours do not moderate the relationship between fluid intelligence and mathematics performance.

H_A4: Problem-solving behaviours moderate the relationship between fluid intelligence and mathematics performance.

H_O5: Study milieu does not moderate the relationship between fluid intelligence and mathematics performance.

H_A5: Study milieu moderates the relationship between fluid intelligence and mathematics performance.

Research methods and design

Design and setting

A non-experimental, quantitative cross-sectional research design was employed to collect data from Grade 9 learners between August and October 2022. Grade 9 learners were targeted since they are in their final year of Senior Phase and at the point of deciding whether to continue pursuing Mathematics or Mathematics Literacy. By the end of the Grade 9 school year, learners should have also demonstrated competence in a variety of mathematical concepts (Department of Basic Education [DBE], 2011).

Sampling strategy

Given the analyses performed, G*Power v3.1 (Faul et al., 2007) determined that a sample of 146 ($\alpha = 0.05$; power = 0.95) was sufficient to evaluate the predictive power of six predictors (fluid intelligence, study attitude, mathematics anxiety, study habits, problem-solving behaviour, study milieu). The researcher therefore proposed to assess approximately 200 learners, in line with the requirements to conduct statistically powerful analyses. Using a cluster sampling strategy, with the approval of the Gauteng Department of Education, 20 Quintile 5 high schools (where the medium of instruction is English) across Gauteng were telephonically contacted to participate in the study, of which four responded positively. After being emailed with additional information about the study, signed approval was obtained from the school principals, and Grade 9 learners and their parents could voluntarily opt into participating.

Consequently, upon receiving parental consent, 187 Grade 9 learners registered with these schools provided informed assent and completed both questionnaires for this study. All learners indicated their gender, with girls constituting 60.4% of the sample. The majority of the sample indicated their ethnicity as Black African (47.1%), followed by White (15.5%), Indian/Asian (8.6%) and Coloured (5.3%), fairly representative of the ethnic profile of Gauteng (StatsSA, 2016); 23% of the sample preferred not to indicate their ethnic group.

Intervention

Since it was a cross-sectional design, each learner was only assessed once, at a time suitable to them or agreed upon with the school. Upon completion of the questionnaires, participants received an interpretive learner insights report, providing them with development tips based on their cognitive and study orientations profile. The majority of learners also received group feedback to guide their interpretation of these insight reports, and the opportunity for individual feedback was communicated.

Data collection

To assess fluid intelligence, the South African, electronic version of the Raven's Standard Progressive Matrices (SPM) was administered. The non-verbal nature of the questions provides users with a culturally fair, relatively language-free gauge of the participant's fluid intelligence and abstract thinking ability, making it more applicable for our diverse, multilingual South African learner population (Taylor, 2008). The SPM consists of 60 incomplete patterns, and participants had to find the exact fitting piece among 6 to 8 alternatives presented to complete the pattern. The items become progressively more difficult, and all 60 questions have to be answered before the questionnaire can be submitted for scoring. All items load onto a general '*g*' factor, indicative of fluid reasoning. A South African adolescent norm is available, and was used for the current study, for which internal consistency reliability coefficients (Cronbach's α) are 0.90 for both boys and girls, 0.90 for White adolescents and 0.88 for Black adolescents (NCS Pearson, 2018).

The Study Orientation Questionnaire in Mathematics (SOM) is a 76-item South African-developed assessment written in English for learners from Grades 7 to 12. The assessment measures study attitude (14 items), mathematics anxiety (14 items), study habits (17 items), problem-solving (18 items), study milieu (13 items), and information processing (16 items – only for Grades 10, 11 and 12) (Maree et al., 2011). Learners were asked to rate their frequency of behaviours (1 [rarely] to 5 [almost always]) across items. Learners also indicate their most recent Mathematics term mark in the biographical section of the SOM, which asks for the learner's name, surname, grade, and Mathematics mark. For Grade 9 learners, the SOM has internal consistency reliabilities (Cronbach's α) of between 0.72 and 0.79 on the individual scales, and an overall reliability of 0.95 as a measure with English- and Afrikaans-speaking learners, and an overall reliability of 0.89 for learners speaking African languages. The SOM was administered electronically, and the researcher was able to calculate raw total scores for analyses and convert them into percentiles based on the Grade 9 norm available in the SOM manual. Forty-four questionnaires were not completed in their entirety, and therefore could not be scored or used for subsequent analysis. The schools also verified the mathematics marks of the learners who completed the questionnaires, to verify the marks indicated by the learners were correct.

Data analysis

The analyses on the data set of 187 learners were performed using Jamovi version 2.2.5 (The Jamovi Project, 2021). The R packages used within the Jamovi programme for specific analyses are discussed in the sections below. It should also be noted that for all analyses, only raw scores were used, given that the mindset items have no standardised or normed scores, and that the Bertelsmann Stiftung's Transformation Index (BTI) does not report on percentile scores like the SPM and SOM.

Pearson correlation coefficients were calculated using the *jmv* package to determine inter-factor correlation coefficients between the Ravens and SOM, since both assessments measured their variables on an interval scale. These inter-factor Pearson correlation coefficients serve to inform whether the hypothesised statistical relationships directly exist between the variables (Schober et al., 2018). In addition to noting the statistical significance of the correlations, the strength and direction of the relationships between variables were interpreted using the guideline of correlation coefficients in the range of 0.1–0.3 to represent small (weak) magnitudes, 0.3–0.5 medium (moderate) magnitudes, and 0.5–1.0 large (strong) magnitudes (Gignac & Szodorai, 2016). Although not directly relevant to the stated objectives and hypotheses, determining the correlations between mathematics performance, fluid intelligence, and study orientations helps interpret subsequent analyses. Additionally, these inter-factor correlation matrices were inspected for potential multicollinearity before being investigated further with both linear and multiple moderating regressions.

To achieve the first objective of this study, of determining whether fluid intelligence and study orientations predict mathematics performance, a linear regression was conducted. Fluid intelligence and each of the study orientation factors were added into the linear regression model as independent predictor variables. Additionally, dominance analysis was used to assess the relative importance of each of these predictor variables in explaining variance in mathematics performance (Braun et al., 2019). Dominance analysis was performed with version 2.0-3 of the *yhat* package in R and is a technique used to compare the relative importance of predictors in a regression model (Nimon et al., 2021).

The second objective of this study was to explore the interaction between cognitive (fluid intelligence) and behavioural (study orientations) factors. Moderation analysis examines how a relationship between a predictor and outcome variable is influenced by a third variable, known as the moderator. The results of such analysis can determine whether the relationship between predictor and outcome variables weakens, strengthens, or exists at all in the presence of the moderating variable (Hair et al., 2021). The inter-factor correlation analysis provided insight into the variables that would be theoretically meaningful to include to test for the existence of moderating relationships (Hayes, 2018). Therefore, the existence of potential moderating relationships was tested using the *medmod* module in Jamovi. This module enables simple moderation analyses, between a single predictor variable, a single outcome variable, and a single independent moderator, without needing to manually mean centre any of the variables (Selker, 2017), a valuable consideration when multicollinearity (which was found between the variables) may increase the instability added to the regression model (Iacobucci et al., 2017). For the moderating analyses, the fluid intelligence factor was set as the predictor variable, mathematics marks were set as the outcome variable, and the study orientation factors were each tested as an independent moderator variable.

Ethical considerations

Prior to any interaction with learners, ethical clearance from the Research Ethics Committee from the University of Pretoria (HUM035/0721) and permission from the Gauteng Department of Education were obtained. Thereafter, principals in the Gauteng region were contacted and interested schools then assisted the researchers in communicating the purpose of the study and the voluntary nature of participating to learners and parents. Learners wanting to participate communicated their interest to their teachers or the researchers directly, and suitable times for test administration were allocated. Physically signed copies of both parental consent as well as learner assent were required before learners could complete the questionnaires. All questionnaires were completed electronically under the supervision of the researcher, which minimised the risk of checking peers' answers or incorrect data capturing. The researcher and the assessment provider have a legal obligation to keep the collected information for a period of 7 years, in line with the Health Professions Council of South Africa's guidelines.

Results

Factor correlation coefficients

Table 1 reports the direction, strength, and statistical significance of the correlations between mathematics marks, fluid intelligence, and the study orientations assessed for this study.

Study attitude reflected a statistically significant, strong, positive relationship with mathematics marks (r = 0.51, $p < 0.001$), supporting the suggestion that a more positive approach to mathematics, where learners see the value of the subject and generally enjoy studying mathematical content, is likely to result in a higher mathematics mark. Study attitude also has a statistically significant, weak, positive relationship with fluid intelligence ($r = 0.27$, $p < 0.001$), which suggests that the self-insight into one's abilities likely positively influences one's study attitudes.

Given the only negative statistically significant moderate correlation, between mathematics anxiety and mathematics marks (r = –0.36, $p < 0.001$), the relationship supports literature that anxiety negatively influences mathematics

TABLE 1: Correlations between mathematics marks, fluid intelligence, and study orientation factors.

Variable	Mathematics mark	*f*	SA	MA	PSB	SH	SM
f	0.39***	-	-	-	-	-	-
SA	0.51***	0.27***	-	-	-	-	-
MA	-0.36***	-0.12	-0.25***	-	-	-	-
PSB	0.47***	0.29***	0.75***	-0.19**	-	-	-
SH	0.46***	0.23**	0.76***	-0.20**	0.79***	-	-
SM	0.41***	0.29***	0.49***	-0.46***	0.36***	0.44***	-
M	57.00	42.30	38.00	15.20	46.20	39.90	42.0
SD	6.00	7.40	9.10	8.80	11.60	11.50	6.8

f, Fluid intelligence; SA, Study attitude; MA, Mathematics anxiety; PSB, Problem-solving behaviour; SH, Study habits; SM, Study milieu; M, mean; SD, standard deviation.
*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$

achievement. The relationship between mathematics anxiety and fluid intelligence was not significant (r = –0.12, p > 0.05). This is expected, given that the fluid intelligence questionnaire did not have mathematical content, since Grade 9 mathematical concepts, such as basic operations (addition, subtraction, multiplication, division) and their various combinations, are learnt over time, classifying them as crystallised information. The non-significant relationship therefore provides support for mathematics anxiety only impacting mathematics performance, while not impacting performance in other domains, such as performance on a fluid reasoning questionnaire.

The relationship between study habits and mathematics marks is statistically significant, moderate, and positive (r = 0.46, p < 0.001), supporting the view that positive study habits positively influence mathematics performance. The statistically significant, weak, positive relationship between study habits and fluid intelligence (r = 0.23, p < 0.01) could be indicative of learners higher on fluid intelligence realising sooner that they do not understand concepts, and so putting in more study effort to grasp the concept confidently.

Problem-solving behaviour displayed a statistically significant, moderate, positive relationship with mathematics marks (r = 0.47, p < 0.001), the second strongest after study attitude. This facet of study orientation also showed the highest, albeit weak, statistically significant positive relationship with fluid intelligence (r = 0.29, p < 0.001). Given that problem-solving behaviour relates to metacognition and applying cognitive strategies effectively to solve problems, it is likely that learners who apply problem-solving skills towards mathematics problems applied similar skills during the completion of the fluid intelligence assessment.

Study milieu also had statistically significant positive correlations with both mathematics marks (r = 0.41, p < 0.001) and fluid intelligence (r = 0.29, p < 0.001). The relationship with mathematics marks suggests that learners who have a more supporting learning environment are more likely to achieve higher mathematics marks. The relationship between study milieu and fluid intelligence is quite insightful, perhaps an indication that more supportive environments (possibly one's home environment) help learners develop a higher level of fluid intelligence from childhood.

Table 1 also reports that study attitude has statistically significant, strong relationships with study habits (r = 0.76, p < 0.001) and problem-solving behaviours (r = 0.75, p < 0.001), a statistically significant moderate relationship with study milieu (r = 0.49, p < 0.001), and a statistically significant, weak, negative correlation with mathematics anxiety (r = –0.25, p < 0.001). Mathematics anxiety has statistically significant, weak to moderate, negative relationships with all the other factors of study orientation – problem-solving behaviours (r = –0.19, p < 0.01), study habits (r = –0.20, p < 0.01), study milieu (r = –0.46, p < 0.001). Problem-solving behaviours further demonstrate statistically significant, positive correlations with study habits (strong: r = 0.79, p < 0.001), and study milieu (moderate: r = 0.36, p < 0.001). Study habits and study milieu also have a statistically significant, moderate, positive relationship (r = 0.44, p < 0.001). While these relationships may be indicative of an overall study orientation towards mathematics factor, when considered in addition to their correlations with fluid intelligence, they are also a flag for potential multicollinearity. As such, subsequent regressions have been performed with mean-centered variables to reduce this multicollinearity effect.

Objective 1: Predictive value of fluid intelligence and study orientations

Table 2 reports the linear regression and dominance analysis conducted to investigate the predictive value of fluid intelligence and the study orientation factors. Collectively, these predictor variables explain 39.0% of the variance in mathematics marks (R^2 = 0.390, F(6, 180), = 19.2, p <0.001). Additionally, it can be noted that only fluid intelligence, study attitude and mathematics anxiety are statistically significant predictors in this model.

In considering the dominance of these predictors, study attitude is seen to be the most dominant predictor in the model, contributing 21.7% towards the total variance explained. Fluid intelligence is ranked as the second-most dominant predictor, with a contribution of 19.3% towards the total variance explained. While mathematics anxiety is ranked as the second-lowest dominant predictor out of the six variables, it is the only other statistically significant predictor, contributing 15.0% towards the total variance explained.

Objective 2: Moderating interactions between fluid intelligence and study orientations

Table 3 reports on the moderation tests conducted, with fluid intelligence (as the predictor variable), each of the study

TABLE 2: Linear regression and predictor ranking on mathematic performance.

Predictor	Estimate	Standard error of the estimate	95% confidence interval		t	p	Standardised dominance statistic	Rank
			Lower	Upper				
Intercept	18.853	8.497	2.086	35.621	2.219	0.028	-	-
f	0.512	0.135	0.245	0.778	3.789	< 0.001	0.193	2
SA	0.378	0.177	0.030	0.727	2.141	0.034	0.217	1
MA	-0.375	0.120	-0.612	-0.138	-3.123	0.002	0.150	5
SH	0.137	0.146	-0.151	0.425	0.941	0.348	0.155	4
PSB	0.135	0.144	-0.149	0.420	0.938	0.350	0.163	3
SM	0.144	0.176	-0.203	0.491	0.821	0.412	0.122	6

f, Fluid intelligence; SA, Study attitude; MA, Mathematics anxiety; PSB, Problem-solving behaviour; SH, Study habits; SM, Study milieu.

orientations (moderator variable), and mathematics marks (as the dependent variable).

From Table 3, it is noted that significant, positive main effects were found between fluid intelligence and mathematics marks in all five models. Additionally, the positive main effect between each of the study orientation factors and mathematics marks was significant, which is somewhat contradictory to the linear regression reported in Table 2. These statistically significant direct effects may be an effect of multicollinearity, despite the variables being mean-centred in the linear model. What can be noted from the results of the moderation models, however, is that fluid intelligence and all the study orientations have a direct effect on mathematics performance.

Considering moderated relationships, however, only study milieu is seen to have a significant interaction effect with fluid intelligence (b = 0.044, 95% CI [0.011, 0.077], z = 2.600, p < 0.01). As such, except for study milieu, study orientations do not moderate fluid intelligence. The results therefore fail to reject the null hypotheses H_O1, H_O2, H_O3, and H_O4. However, the results support a rejection of the null hypothesis H_O5, in favour of the alternative hypothesis, H_A5. Table 4 describes this interaction effect further, showing the effect of fluid intelligence on mathematics marks at different levels of study milieu scores.

From Table 4, it can be interpreted that learners who reported higher than average levels of study milieu were able to achieve higher mathematics marks in accordance with their fluid intelligence potential (b = 1.001, 95% CI [0.606, 1.396], z = 4.970, p < 0.001), when compared to average or lower than average levels of study milieu (b = 0.703, 95% CI [0.428, 0.979], z = 5.000, p < 0.001 and b = 0.405, 95% CI [0.091, 0.720], z = 2.530, p = 0.01). As such, it can be concluded that the more learners perceive a positive study milieu, the more likely learners are to achieve in mathematics and actualise their cognitive potential, as assessed by fluid intelligence. This finding further brings to our attention that even if learners possess higher levels of cognitive potential, if they do not have conducive learning environments, their mathematics performance will ultimately be negatively impacted. At this point, it should again be noted that the current study was conducted in Gauteng, a province where both socioeconomic status and mathematics performance are generally higher, compared to other provinces in South Africa (apart from Western Cape) (Gondwe, 2022). Given that the results showed the effects of the study milieu in an urban area where learners had access to resources such as computer labs and internet connection, it is believed that the impacts will be more profound in a rural milieu. Therefore, this finding adds support to public pleas for more resources to be invested in educational systems, for learners to be able to actualise their potential.

TABLE 3: Direct effects and moderation models: Fluid intelligence and study orientations.

Predictor	Estimate	Standard error of the estimate	95% confidence interval		z	p
			Lower	Upper		
f	0.596	0.131	0.340	0.852	4.563	< 0.001
SA	0.773	0.106	0.566	0.981	7.312	< 0.001
f × SA	0.010	0.015	-0.020	0.040	0.662	0.508
f	0.757	0.138	0.488	1.027	5.502	< 0.001
MA	-0.568	0.116	-0.795	-0.341	-4.904	< 0.001
f × MA	-0.003	0.016	-0.034	0.029	-0.159	0.874
f	0.633	0.136	0.366	0.899	4.653	< 0.001
SH	0.543	0.085	0.377	0.709	6.409	< 0.001
f × SH	-0.005	0.011	-0.027	0.017	-0.425	0.671
f	0.602	0.141	0.326	0.878	4.270	< 0.001
PSB	0.538	0.086	0.369	0.707	6.242	< 0.001
f × PSB	0.002	0.011	-0.020	0.025	0.198	0.843
f	0.703	0.139	0.431	0.976	5.060	< 0.001
SM	0.822	0.146	0.535	1.109	5.620	< 0.001
f × SM	0.044	0.017	0.011	0.077	2.600	0.009

f, Fluid intelligence; SA, Study attitude; MA, Math anxiety; SH, Study habits; PSB, Problem-solving behaviour; SM, Study milieu.

TABLE 4: Simple slope analysis: Fluid intelligence and study milieu interaction effect.

Variable	Estimate	Standard error of the estimate	95% confidence interval		z	p
			Lower	Upper		
Average	0.703	0.141	0.428	0.979	5.000	< 0.001
Low (-1SD)	0.405	0.160	0.091	0.720	2.530	0.010
High (+1SD)	1.001	0.201	0.606	1.396	4.970	< 0.001

SD, standard deviation.

Discussion

The relationships between both fluid intelligence and study orientations, and mathematics marks suggested that both cognitive and behavioural factors influence mathematics performance in Grade 9 learners. The relationship between fluid intelligence and mathematics performance was expected and replicated a number of previous studies (Brandt & Lechner, 2022; Hilbert et al., 2019). The relationships between the study orientation factors and mathematics marks also echoed other local studies by Erasmus (2013), Maree et al. (2014), and Morse (2022). However, the insight gained by the current study is that of the relationships between fluid intelligence and study orientations. It was noted that fluid intelligence has weak, statistically significant relationships with all aspects of study orientation except mathematics anxiety. However, it could not be determined whether if, because learners possess higher levels of fluid intelligence, and by association may find mathematics easier to perform in, they also display more positive study orientations towards the subject. These relationships between fluid intelligence and study orientation were therefore examined further with a number of regression techniques.

The linear regression indicates that fluid intelligence, study attitude, and mathematics anxiety are statistically significant predictors of mathematics performance. Additionally, study attitude was found to be the most dominant predictor, followed by fluid intelligence. Despite mathematics anxiety being a significant predictor, it was not ranked as a dominant predictor. These findings contradict Erasmus (2013), who found that while these factors did correlate with mathematics performance, they did not predict it. The findings do, however, add to Morse (2022), who found that the interaction between mindset, mathematics anxiety, and study attitude predicted mathematics performance. Practically, the current results guide educators on where to begin their development initiatives: study attitudes. Previous local studies, such as Mabena et al. (2021) noted learner disinterest towards mathematics, and Mazana et al. (2019) found that study attitude declines from primary school to high school. The current study therefore highlights the need for educators and parents to continuously cultivate positive study attitudes towards mathematics to create excitement and interest in the subject. In this regard, Ramirez et al. (2018) suggest including mathematical board games, interactive classes, and even tuition to enhance study attitudes (while reducing mathematics anxiety and improving mathematics performance), especially when learners underperform and are unlikely to find mechanisms to motivate themselves to try again (King et al., 2012). This finding also encourages changes for an engaging and interactive curriculum that highlights the real-world applications of mathematical concepts. By making mathematics practical, learners' interest and motivation is likely to be enhanced far more, regardless of whether they have the innate intelligence (which cannot be as easily developed) to perform well in mathematics.

Finally, the moderation models shed additional light on the interactions between fluid intelligence and study orientations, in a way that the correlations could not do. Despite the significant relationships between the factors, it was found that, with the exception of study milieu, study orientation does not moderate the effect of fluid intelligence on mathematics performance. Instead, study orientation independently and directly predicts mathematics performance. The implications of these findings are significant, in that they indicate that mathematics achievement is not reliant on fluid intelligence alone. A learner that has a positive study attitude, is confident in their mathematics abilities (low mathematics anxiety), consistently follows through on their effective study practices, and reflects on their problem-solving style is as able to achieve a mathematics pass as a learner with higher fluid intelligence. In considering the significant interaction effect between study milieu and fluid intelligence, it should also be noted that each factor also independently predicts mathematics performance. In saying this, a learner who may not inherently be higher on fluid intelligence may benefit more from a supporting learning environment. However, the findings also express that all learners' mathematics performance may be enhanced with a supporting learning environment.

Strengths and limitations

One of the key strengths of this study is that it gives practical guidance to the education system on what to focus on to improve mathematics performance in the country. The study was able to evaluate the role of both intelligence and behaviour in predicting mathematics performance. The results are able to spread hope to those who are not inherently able to deal with abstract concepts, such as those commonly discussed in mathematics. By actively and consistently working at improving one's mathematics knowledge, one is able to develop a more positive, confident attitude towards the subject. The findings can also be preliminarily used to advocate for changes to the curriculum to make it more practical and engaging for learners. The results also suggest that the value of supportive learning environments should not be overlooked, and educators should be held to such standards that they are able to provide such support to learners.

However, the study is not without limitations. The study was limited to a relatively small, Quintile 5 sample of Grade 9 learners in the Gauteng province, who completed the study during Term 3 of the academic year when fatigue has set in. Having only a single indication of a learners' mathematics achievement and study orientation, while cost-effective, is not ideal. Noting the number of relationships between variables, there are still unanswered questions relating to the stability of study orientations over an academic year, when it is expected that a learner's mathematics performance does fluctuate somewhat. While it is noted that Term 2 mathematics marks were requested, some learners may have had subsequent mathematics tests post their mid-year examinations, and it cannot be said with certainty that they responded to the questionnaires with their Term 2 performance in mind. Additionally, the study primarily relies on self-report measures for study orientations. Self-report measures can introduce bias, as participants may provide responses they believe are socially desirable or may not accurately reflect their behaviours. Furthermore, examining the mediating role of these variables is also an aspect that has not been explored at all for the current study, but can add an additional layer of interpretation and understanding of the interaction between these constructs.

Recommendations

To enhance the generalisability of findings to advocate for curriculum change and psychometric profiling within schools, while also providing context-specific recommendations where possible, it is recommended that future research encompasses a more diverse and representative participant pool. Additionally, given the reliance on self-report measures for study orientations in the current study, future research should explore alternative assessment methods, such as parent and teacher ratings, to mitigate potential biases. It is also recommended that a longitudinal study, across a number of years, at regular intervals within an academic year, be conducted to comprehensively identify at which stage of the learners' scholastic career study attitudes become more negative, or when mathematics anxiety starts crippling performance. Such a longitudinal study can also provide insights to enable educators and parents to actively manage negative study orientations before they have long-term negative implications on mathematics performance. In this light, research that includes a pre- and post-intervention assessment of study orientations, for a more pointed approach towards the factors that have the greatest impact on mathematics performance, beyond the study milieu, is also valuable. Additional studies could also explore specific aspects of milieu, and include teacher attitudes, parent socioeconomic status, and cultural influences.

Conclusion

The current study reiterated that mathematics performance cannot be solely attributed to cognitive abilities. This study concludes with the proposal that a holistic approach to mathematics achievement is needed. The change needs to start at a curriculum level, to make the subject more practical and engaging. Furthermore, educators need to be trained to provide a safe, judgement-free environment that is not only conducive to learning, but that develops a learner's resilience towards mathematics. Educators and institutions should not only focus on academic content but also consider and address the psychological and environmental factors that impact learners' mathematics performance. By creating supportive study environments, parents and teachers should focus on encouraging realistic, yet challenging study habits that learners can gain comfort in following through. Continuous practice not only will reduce nervousness over time, but will also build confidence and a positive attitude towards this essential skill. As learners practise more, thereby implementing their routine study habits, they will also likely become more comfortable with identifying which strategies need to be used with which types of mathematics problems and, in doing so, build their problem-solving behaviours. Implementing targeted interventions and creating a positive, supportive learning environment can contribute significantly to improved mathematics performance for Grade 9 learners, during a time when they are particularly vulnerable as they make subject-choice decisions that will have long-lasting implications not only for their future careers, but for the country at large.

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Competing interests

P.R. is employed by JVR Psychometrics, the official South African suppliers of the psychometric assessments used in the current study.

Authors' contributions

This article is an output from P.R.'s doctoral thesis, which B.M. supervised.

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Data availability

The anonymised data set is available on request, and is in the University of Pretoria's archives.

Disclaimer

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