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How the relationship between individual and social factors informs the narrowing of gender gaps in elementary mathematical achievements

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Few scholarly studies have examined gender gaps vis-à-vis various types of mathematical problems by controlling for individual factors (e.g., general intelligence and self-regulated learning [SRL]) and social factors (e.g., the school's socioeconomic status [SES]) among elementary school students, as addressed in this study. Achievements on three types of mathematical tasks (operations with numbers, geometry, and word problems) and general intelligence scores were obtained from elementary school students. Information regarding students' SRL was obtained from a rating scale designed for the teachers. Results showed that boys' achievements were significantly higher in word problem-solving and geometry tests but not in operation with numbers tests. The results concerning word problems suggest that the effect of the school's SES level on the gender gap decreased in accordance with the increase in the school's SES level. The significant interaction between gender and SRL indicated that the effect of students' SRL level on the gender difference in the students' performance on the geometry test increased in accordance with the increase in the SRL level. General intelligence contributed to individual differences in word problems and geometry, but not on operations with numbers. The analyses showed that SRL contributed to mathematical performance in all tasks. Directions for future research and implications for narrowing these gender gaps are discussed.

KEYWORDS

gender gaps, general intelligence, mathematical achievements, self-regulated learning, socioeconomic status

1 Introduction

The academic literature is abundant with research exploring the factors that impact students' mathematics achievements. Researchers around the world have been seeking to understand how various factors impact directly or indirectly—or even intersect—to influence the mathematical performance of students of all ages (Sakiz et al., 2012; Ghasemi et al., 2019). Over the past decade, many studies have investigated the magnitude and variables explaining mathematical achievements. Given that mastering mathematical manipulations and problem-solving requires higher-order thinking, factors relating to cognitive abilities have been widely examined. Intelligence is a prominent factor that has been repeatedly investigated (e.g., Semeraro et al., 2020). Self-regulated learning (SRL), wherein the students plan how to solve a mathematical task, monitor their own processes, and then reflect on the outcome, is an essential factor in successful mathematics learning (Cleary and Kitsantas, 2017). Students' beliefs have also been found to impact mathematical achievements. Some studies revealed that positive attitudes have been linked to increased school achievement and higher scores on standardized tests (Chen et al., 2018). Another factor is students' motivation and self-efficacy in mathematics, which were also determined to be predictors of students' mathematics achievements (Pinxten et al., 2014; Seaton et al., 2014; Cleary and Kitsantas, 2017).

Many variables relating to the students' developmental and social environment have been identified as dominant predictors of students' performance in mathematics. One of the best indicators of school performance in general and mathematical achievement in particular is family SES. In 95% of the countries, students with higher family SES performed significantly better on the PISA mathematics test (Chiu and Xihua, 2008; Levpušček et al., 2013). Students from more educated homes performed better on TIMSS than those from less-educated homes (Wiberg, 2019). Parental education and professional occupation are used as SES measures across studies and are considered highly influential factors in students' mathematical education (Sirin, 2005). Mathematical performance is also related to other SES components, such as family income and educational resources available to the student at home. Moreover, parental involvement has a well-documented role in children's education (Fan and Williams, 2010). Students with parents who are involved in school events, tend to be more motivated to study and perform better academically than their counterparts with less involved parents (Fan and Williams, 2010). Student-perceived parental and teacher mathematics behavior are influential factors in math achievements (Sakiz et al., 2012). Teachers' affective and academic support was found to be related to students' mathematics achievement (Yu and Singh, 2018). School context and the students' background have an impact on the students' TIMSS mathematics results (Wiberg, 2019). We have not yet mentioned other factors that impact students' mathematical performance, such as culture, mathematics anxiety and/or test anxiety, and classroom climate.

A thorough review of the literature shows that very little research examines the relationship between individual and social factors in predicting achievement in mathematics (Levpušček et al., 2013). Therefore, the main aim of this study was to comprehensively examine the gender differences in mathematical achievements and to explore whether individual (i.e., general intelligence and SRL) and social (i.e., SES) factors are related to these differences. The unique feature of this study was the investigation of the gender differences in elementary students' performance in three types of mathematical tasks: operations with numbers, geometry, and word problems. Investigation of these combined relationships is rare in literature. We chose to conduct this study among young elementary school students. There is broad scholarly agreement that students who do not meet the required learning standards in mathematics by the end of elementary school have a lower chance of succeeding in general mathematics courses in upper secondary school and beyond (Levpušček et al., 2013).

1.1 Gender gaps and mathematical achievements

Gender gaps in mathematical achievements constitute a long-standing, worrisome issue, as scientists attempt to understand the reasons for the low number of women at the top levels in the fields of science, technology, engineering, and mathematics (STEM; Halpern et al., 2007; Cheryan et al., 2017; O'Dea et al., 2018). The existence and magnitude of gender gaps in mathematical performance vary due to numerous factors, including socioeconomic status, nationality, ethnicity, and age (Else-Quest et al., 2010; Steinmayr et al., 2014; Reilly et al., 2015; Hutchison et al., 2019). Moreover, there is evidence that the detection of gender gaps may depend on how mathematics problems are presented to the students, how skills are measured, and the sociocultural experiences children are exposed to (Else-Quest et al., 2010; Miller and Halpern, 2014; Ghasemi and Burley, 2019; Borgonovi and Greiff, 2020). Ghasemi and Burley (2019) conducted a comprehensive study exploring vast international data sets. Their analyses revealed that, there are generally very small differences between genders when it comes to how much they value, enjoy, and are confident in mathematics. The researchers observed that the magnitude of the differences varied among the nations. In addition, an increase in the gender gap was observed between the fourth and eighth grades. Even though the differences were minimal, and the growth was very small, it might indicate a rising trend in gender differences as students grow.

The origin of gender differences in mathematics has also been attributed to sociological influences. Stereotype threat has been shown to have damaging effects on girls' mathematical performance (Jones and Wheatley, 1990; Doyle and Voyer, 2016). For example, it is possible that girls' exposure to mathematics differs from boys', leading to differences in mathematical abilities among school-age children. According to earlier studies (Duffy et al., 2001; Leyva, 2017), math teachers are more likely to encourage boys to ask questions, respond, and explain concepts. There has also been an association between gender gaps in mathematics and parental assessments of their children's abilities. According to several studies parental expectations of their children's abilities have been linked to their self-perception of their own abilities and subsequent performance (Jacobs and Eccles, 1992; Bleeker and Jacobs, 2004; Del Río et al., 2019).

Little empirical evidence exists regarding gender gaps in various types of mathematical problems by addressing general intelligence, SES, and SRL capabilities among elementary school students (e.g., Spinath et al., 2014). Addressing these issues is critical, given the importance of understanding how these factors intersect to influence the mathematical performance of young schoolchildren (Ghasemi et al., 2019). Moreover, such an investigation may yield insights into how SES levels are related to gender differences in mathematical achievements.

1.2 Gender differences and similarities in elementary school mathematics

A large corpus of research has documented differences in the mathematical performance of girls and boys. However, these studies' findings are inconsistent: According to certain research, boys generally did better than girls on mathematical tasks (e.g., Halpern et al., 2007; Zhu, 2007; Gilleece et al., 2010; Robinson and Lubienski, 2011; Reilly et al., 2015; Stoet and Geary, 2018), while others showed a diverse range of gender differences depending on the type of mathematical tasks (e.g., Voyer et al., 1995). Meta-analyses have indicated no differences (Hyde et al., 2008) or only negligible differences (Reilly et al., 2015) in mathematics achievements between boys and girls in Grades 4, 8, and 12. Reilly et al. (2019) presented findings from the 2011 Trends in Mathematics and Science Study (TIMSS), a comprehensive worldwide evaluation of students' performance in the eighth grade. In the majority of countries, the meta-analysis found minor to moderate gender differences (from $d = -0.60$ to $+0.31$). However, several studies did point out the existence of gender differences in mathematical problem-solving (Ben-Chaim et al., 1988; Royer et al., 1999; Gallagher et al., 2000; Zhu, 2007).

According to research, there are age-dependent gender differences in mathematics. When kindergarten begins, there is no discernible difference in boys' and girls' mathematical abilities; however, by the end of the year, boys have an obvious advantage (Penner and Paret, 2008; Lubienski et al., 2013). According to Robinson and Lubienski (2011), the average gap between girls and boys peaks at roughly 0.24 standard deviations in the third and fifth grades. Reilly et al.'s (2015) meta-analysis indicated only very slight gender differences in elementary and middle school years, which grew more significant by the last year of high school.

1.3 Gender differences and the type of mathematical problem

Contextual factors, including the type of the mathematical problem being evaluated, may influence gender differences.

1.3.1 Operations with numbers

Prior research suggested that when it came to calculation and arithmetic examinations (i.e., complicated multiplication, simple subtraction, etc.) requiring relatively easy cognitive processes, girls might do just as well as, or perhaps better than, boys (e.g., Hyde et al., 1990; Fennema et al., 1998; Else-Quest et al., 2010; Wei et al., 2012). Girls in the sixth grade outperform boys not only in arithmetic tasks but also in numerosity comparison, number comparison, number series completion, choice reaction time, and word-rhyming tasks (Wei et al., 2012). According to Fennema et al.'s (1998), boys tended to employ more abstract techniques that show conceptual knowledge, whereas girls tended to use more concrete strategies (i.e., modeling and counting) that explain the problem and symbolize its solution. Other studies show that by the end of the third grade, girls use more standard algorithms than boys do (Fennema and Carpenter, 1998; Che et al., 2012; Laski et al., 2013). However, Wei et al. (2016) found that gender differences in arithmetic performance disappeared after controlling for spatial ability.

1.3.2 Word problem-solving

Studies revealed that boys' advantages in mathematics emerged on tasks requiring higher order cognitive processing, such as complex problem-solving (e.g., Benbow and Stanley, 1983; Hyde et al., 1990; Geary, 1996; Zhu, 2007; Hyde et al., 2008; Else-Quest et al., 2010; Wei et al., 2012). Björn et al.'s (2016) study investigated the gender differences in the relationships between text comprehension and word problem solving in mathematics. The findings demonstrated that proficient reading comprehension in Grade 4 predicted proficient word problem solving in arithmetic at subsequent grade levels. Girls' success on arithmetic word problems in Grade 9 was predicted by their strong text comprehension abilities in Grade 4. Fatqurhohman's (2021) study also determined gender differences on mathematical word-problem skills in the seventh grade, indicating that boys outperformed girls. The author suggested that boys comprehension skills, and accuracy regarding word problems are better than that of girls.

1.3.3 Geometry

Geometry is defined as the mathematics of space (Bishop, 1986). Mathematical educators have addressed spatial ability as the element of geometry and suggested that spatial ability is a key determinant in geometry achievement and problem-solving abilities in geometry (Battista, 1990; Gorgorió, 1998; Ubuz et al., 2009; Erdoğan et al., 2011). One domain where gender differences favoring boys are evident is in spatial processing (e.g., Halpern et al., 2007; Levine et al., 2016; Gilligan et al., 2017; Hutchison et al., 2019). Hutchison et al. (2019) suggested that boys (ages 6 to 13) are more prone to rely on spatial strategies while solving fundamental numerical problems. Battista (1990) suggested that in high school geometry, boys and girls differ in spatial visualization and in their performance. The differences emerge in comprehension of basic concepts, techniques, and principles, as well as in the ability to apply comprehension to new situations. However, other studies revealed no gender differences in students thinking levels in geometry in elementary (Bal, 2014) and high school (Alex and Mammen, 2014).

1.4 Factors that contribute to gender gaps in elementary school mathematics

1.4.1 Socioeconomic status

Scholarly literature has defined socioeconomic status (SES) in various ways. SES is commonly represented as the level of parents, income and education and family resources (Sirin, 2005). A majority of academic studies have focused on individual or family SES, corroborating a strong and consistent relationship between SES and learning achievements (Gabriel et al., 2016; White et al., 2016).

SES has been found to be strongly related to achievements in mathematics (Jordan et al., 2007; Penner and Paret, 2008; Cheema and Kitsantas, 2014; Garon-Carrier et al., 2018; Zhu et al., 2018). Recent studies have indicated that students from low SES families outperform those from middle SES families on a range of cognitive tasks related to mathematical achievement (Lee et al., 2016; Zhu et al., 2018). Compared to their low SES peers, children from high SES families typically possess more sophisticated number skills, such as counting, ordering, and comparing numbers, even before entering kindergarten (Starkey et al., 2004). Compared to their peers from high SES backgrounds, children from low SES significantly underperform on tasks involving spatial orientation and spatial visualization (Levine et al., 2005; Dearing et al., 2012; Elliott and Bachman, 2018).

Preschoolers from low SES are less proficient than their higher SES counterparts in naming, manipulating, and reproducing patterns (Starkey et al., 2004). Few studies examined gender variations in spatial abilities among children from low-income families (Levine et al., 2005; Tzuriel and Egozi, 2010; Garon-Carrier et al., 2018).

School SES is the total SES of all students enrolled at a specific school. Research suggests that school SES is a stronger predictor of academic achievement than home SES (Perry and McConney, 2010; Marchant and Finch, 2016). Therefore, this study focused on school

SES and examined the relationship between different levels of school SES and young students' mathematical performances. This study also sought to further examine the differential relationship between different SES groups, and other factors related to student mathematics performance, such as general intelligence and self-regulated learning capabilities.

1.4.2 General intelligence

General intelligence, measured by childhood psychometric test scores, strongly predicts academic achievements (Deary et al., 2007; Calvin et al., 2010; Paz-Baruch, 2020). Intelligence is viewed as a relatively stable characteristic that is influenced by environment and heredity (Sternberg, 1999). Cattell (1963) submitted that general intelligence is a combination of fluid intelligence and crystalized intelligence. Fluid intelligence, the reasoning and problem-solving ability, is strongly related to cognitive abilities such as comprehension and learning, but it does not rely on prior knowledge. Fluid intelligence has been defined as the ability to solve new and complicated problems through mental processes like inference-drawing, concept formation, classification, relation identification, problem-solving, and so forth (Cattell, 1963; Newton and McGrew, 2010).

On the other hand, crystallized intelligence relies on previous experiences, learned procedures, and knowledge. According to several studies, the correlation between fluid intelligence and academic achievements has an effect size of moderate to large (correlation of around 0.50; Neisser et al., 1996; Peng et al., 2019). In their study, Calvin et al. (2010) demonstrated that after controlling for the variance derived from general intelligence, boys' mean scores on the quantitative residual factor was higher than that of girls ($d = 0.28$). The authors suggested that gender differences in educational achievements cannot be explained by general cognitive ability. However, boys showed a slight advantage in quantitative reasoning abilities while girls had the advantage in verbal ability. It was these cognitive specializations that contributed to gender differences in elementary school grades.

1.5 Self-regulated learning

The terms metacognition, self-regulation, and self-regulated learning (SRL) are commonly discussed and examined in educational literature (Dinsmore et al., 2008). Metacognition refers to an individual's knowledge, regulation, and control of the processes of their own cognitive system (Flavell, 1976). Self-regulation pertains to the process by which individuals control their own behavior, thoughts, or emotions (Bandura, 1991). SRL is a complex concept that emphasizes a learner's proactive engagement (Pintrich, 2004; Zimmerman and Schunk, 2011).

Self-regulated learning emphasizes the active role of the learner (Boekaerts, 1996; Pintrich, 2004; Zimmerman, 2008). SRL involves establishing personal learning goals and working to achieve them. Cognition, metacognition, motivation, affect, and volition are key elements of SRL (Boekaerts, 1996). Different theoretical models of SRL emphasize various components, yet they unanimously define SRL as a comprehensive process encompassing the monitoring and controlling of behavior, cognition, motivation, and the environment (Efklides, 2011).

Numerous SRL frameworks detail how students manage their learning processes (Boekaerts and Niemivirta, 2000; Azevedo et al., 2010). While these models offer varied insights into SRL, they all agree that self-regulated learners are actively involved in constructing knowledge and employ a range of cognitive and metacognitive strategies to oversee and direct their academic achievements (Zimmerman, 2000). Self-regulated students are characterized as those who effectively manage their learning by using strategies that help them succeed in the learning task and are able to assess the usefulness of those strategies (Zimmerman, 2000). Students are described as being self-regulated to the extent that they know and employ a variety of learning strategies, as well as deciding on when, why, and how to use these strategies in appropriate contexts (Zimmerman, 2000; Dent and Koenka, 2016). According to studies, students who practice SRL strategies also score higher on academic tests and other evaluations of their performance and accomplishment (Zimmerman, 2008; Rosário et al., 2013). Studies show that when it comes to completing academic assignments, SRL students are more involved, consistent, and persistent than their low SRL peers (Zimmerman, 2008; Eilam et al., 2009).

Most theoretical models of SRL include distinctive phases (e.g., Pintrich and Zusho, 2002). In the first stage, motivational beliefs and values are employed as students plan their course of action. Setting goals is an important part of this process (Pintrich, 1999). During the second phase, the self-regulated learner chooses and adjusts cognitive strategies suitable for the current task (Pintrich and Zusho, 2002). Additionally, the learner engages in metacognitive processes that provide feedback on the efficacy of a given strategy. The third phase involves the students putting the strategies into practice and monitoring their progress. During the fourth phase, a link between the learning achievement and the strategic process is made. At last, students return to the initial phase and monitor their progress.

Studies on gender differences in students' use of SRL strategies often favor girls (Pokay and Blumenfeld, 1990; Wolters and Pintrich, 1998; Pajares and Valiante, 2001; Pajares, 2002; Khanal, 2017). For example, Zimmerman and Martinez-Pons (1990), who examined gender differences in students' use of SRL strategies, revealed that compared to boys, girls were more likely to keep records, use goal-setting and planning techniques, and self-monitor more often. Pokay and Blumenfeld (1990) examined how high school geometry students used SRL strategies. They found that girls reported using more specific, metacognitive, and general cognitive strategies than boys. Girls also reported stronger effort management. Khanal's (2017) study examined gender differences in learning strategies in mathematics. The results showed that boys preferred to employ elaboration (i.e., summarizing information and putting ideas into their own words), effort management, and critical thinking strategies, whereas girls preferred to use peer learning, help-seeking, and rehearsal strategies. Bezzina's (2010) study among eleventh-grade students examined gender differences in mathematical performance and in SRL. The study results suggested that the effect of gender on mathematical performance is no longer significant after controlling for students' use of SRL strategies.

Considerable research has linked SRL strategies and academic achievements (Zimmerman and Schunk, 2011; Dent and Koenka, 2016), but some researchers have started to doubt the suitability of using self-report questionnaires to measure SRL strategy use (Winne and Jamieson-Noel, 2002). Researchers consider new methods as more valid for assessing students SRL in real time (Schellings and Van Hout-Wolters, 2011). Alternative SRL assessment tools include, for example, direct observations (Whitebread et al., 2009; Spektor-Levy et al., 2017), tracing think-aloud protocols (Vandevelde et al., 2015), and rating scales designed for teachers (Cleary and Callan, 2014). For these reasons, we used teachers' ratings of student SRL capabilities in the current study.

1.6 The current study

This study is a cross-sectional study type in which we analyzed the relations between various data variables gathered from an elementary student population, at a specific point in time (Levin, 2006). The main aim of this study was to comprehensively examine the gender differences in mathematical achievements (in three types of mathematical tasks) and to explore whether they are related to individual (i.e., general intelligence and SRL) and social (i.e., school SES) factors. Our research questions were as follows:

1. Whether and to what extent are there gender differences in mathematical achievements in three types of mathematical tasks among elementary school students?
2. What are the relations between individual factors (i.e., general intelligence and SRL), social factors (i.e., school SES) and gender differences in mathematical achievements in different types of mathematical tasks?

The first research hypothesis was that differences would be found between boys and girls in the three types of mathematical tasks. We hypothesized that girls' achievements in operations with numbers tasks would be higher than boys. This hypothesis is based on previous studies demonstrating that girls may do as well as, or even better than boys on tests of computation and arithmetic tasks (e.g., Fennema et al., 1998; Else-Quest et al., 2010; Wei et al., 2012; Räsänen et al., 2021). We also assumed that boys' achievements in word problems and geometry would be higher than girls. This hypothesis is based on previous studies regarding boys' higher spatial processing, which affect their geometry performance (e.g., Levine et al., 2016; Gilligan et al., 2017) and studies regarding boys higher mathematical word problems skills (Fatqurhohman, 2021).

The second research hypothesis was that the gender gaps would be related to individual (i.e., general intelligence and SRL) and social (i.e., school SES) factors. We assumed that SES, students' general intelligence, and SRL capabilities would impact the gender gaps on each mathematical task, which means that SES, SRL, and general intelligence will moderate the gender gaps on each mathematical task. This hypothesis is based on previous studies addressing the relations between SES and students' mathematical performance (Lee et al., 2016; Zhu et al., 2018) and studies regarding the importance of SRL strategy use and the impact of general intelligence on gender gaps in mathematical performance (Bezzina, 2010; Peng et al., 2019).

This study may contribute to the large body of studies in this field based on our deliberate attempt to include individual and social factors that may contribute to gender gaps in various mathematical tasks. To date, only a few studies have examined elementary students' mathematics achievements through a multidimensional lens (Moon et al., 2022). Very few studies have included individual factors such as general intelligence and SRL capabilities to elucidate certain gender differences in a variety of elementary school mathematical tasks. Some studies have separately examined the contribution of SES (e.g., Lee et al., 2016) or SRL (Pokay and Blumenfeld, 1990; Bezzina, 2010) to gender gaps in mathematics. The present study investigated the relations between these variables (general intelligence, SRL capabilities, and SES) and gender differences in various areas of mathematical achievement among young students. Moreover, the results of this study may inform researchers and policymakers on how to narrow the gender gap in mathematics education in elementary grades and beyond.

2 Method

2.1 Participants

The sample size was determined a priori by using the G*power software. For conducting a one-way MANOVA analysis, using the test parameters (low effect size = 0.10, α error = 0.05, power = 0.90, two study groups and three response variables), the total sample size required was 146 participants. In order to increase the power and sensitivity, the present study included 170 participants (91 boys and 79 girls; mean age = 10.70, *SD* = 0.4).

The study had a negligible percentage of outliers, which were removed from the sample (5 participants). Another 4 participants were removed because not all the tests were completed.

The students were sampled from seven elementary schools: two schools from low SES areas (*n* = 42, 24.7%), three schools from middle SES areas (*n* = 83, 48.8%), and two schools from high SES areas (*n* = 45, 26.5%).

The students were from an urban area in Israel. In Israel, there are distinct educational programs for Jewish and secular students as well as for Arab students. Both public and private schools are included in each sector. The students in the study were from the Jewish secular sector. The participants had no learning disabilities or visual impairment.

We obtained the schools' SES levels from the Ministry of Education's Nurturing Index, a social and economic status index that rates schools based on a combination of factors including parental education, immigration status, geographic location, and a school-level income measure (i.e., the median parental income of families in the school). The index values range from 1 to 10. The higher the school's score, the more funding the school is eligible for. Accordingly, in the present study, school values of 1–2 represented high SES, school values of 3–7 represented middle SES, and school values of 8–10 represented low SES. No significant difference in the gender distribution was found between the three SES levels, $\chi^2(1) = 1.55$, $p = 0.460$.

2.2 Measures

2.2.1 Raven's standard progressive matrix

The Raven's Standard Progressive Matrices (RSPM; Raven et al., 2000) test is used to evaluate mental ability related to abstract reasoning and is recognized as a nonverbal evaluation of fluid intelligence. The short version of the test was used to examine students' general intelligence. Correlations (from $r = 0.66$ to $r = 0.91$)

between the shortened version and the full version were found in previous studies (Arthur and Day, 1994; Bors and Stokes, 1998; Hamel and Schmittmann, 2006; Bilker et al., 2012).

In the RSPM, participants are presented with puzzles containing visual patterns with a piece missing. For each item, the participant is instructed to identify the missing piece from a given selection of eight possibilities. The short version of the RSPM contains 30 items. The time limit is 15 min. The score for each correct response is one point and for incorrect response, zero point.

2.2.2 Teacher's rating scale of students' SRL capabilities

The teacher's rating scale was based on the short version of the Nuremberg Gifted Identification Checklist (NGIC; Harder et al., 2015). The reliability, objectivity, and validity of the rating scale were previously investigated by Harder et al. (2015), who revealed that it is of a high diagnostic quality.

10 NGIC items examining self-regulated learning capabilities were used for this study. Each item was presented as a statement of positive learning capability. For example: "The student has above-average verbal skills of expression"; "This student has effective learning strategies"; "This student has the necessary resources (e.g., time management capabilities and learning opportunities) to improve their skill level in a new domain"; "This student sets personally challenging learning goals and is motivated to attain them." Teachers could choose one of three responses: "not true," "partly true," and "totally true." The Cronbach's alpha reliability coefficient in this study was 0.923.

2.2.3 Mathematical achievement

The mathematical achievement tests included three types of mathematical tasks: operations with numbers, word problems, and geometry. The tests were specially designed for this study and were based on the national mathematics curriculum and a nationwide standardized test. Some of the tasks were adapted from the Growth and Effectiveness Measures for Schools exams, the National Authority for Measurement and Assessment in Education (RAMA), Ministry of Education, Israel (see Table 1).

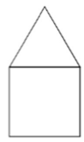
2.2.3.1 Operations with numbers

Operations with numbers included seven tasks of four operations with whole numbers (addition, subtraction, multiplication, and division); comprehension of the place value system and mixed operations (where different operations need to be coordinated). The scoring of each task was based on the difficulty level: low-level exercises received lower scores (i.e., simple addition and subtraction), moderate-level exercises received higher scores (i.e., multiplication and division), and high-level tasks received the highest score (i.e., mixed operations: multiplying first and then adding). The total score for the test was 100. The Cronbach's alpha reliability of this subtest was 0.61.

2.2.3.2 Word problems

The test included eight word problems: multistep word problems, inquiry problems, process-thinking questions (including the ability to connect concepts, adapt a mathematical model to a verbal situation, and find the solution based on insight), open search, and reasoning problems. The scoring of each word problem was based on the difficulty level: low-level word problems received lower scores (i.e., adapt a mathematical model to a verbal situation and multistep word problems), and high-level word problems received the highest score (i.e., open search, and reasoning problems). The total score for the test was 100. The Cronbach's alpha reliability of this subtest was 0.74.

TABLE 1 **Examples of three types of elementary school mathematical tasks.**

Operations with numbers	Geometry	Word problem
4,500:9 42 × 6 539 + 3,234 4,562–1,246 500 × 15	Here is a diagram of a square and an equilateral triangle. The perimeter of the triangle is 15 centimeters. What is the perimeter of the square? 	Johnny circled the gym 5 times. In total, Johnny ran 525 meters. Adam circled the gym 4 times. How many meters did Adam run?

2.2.3.3 Geometry

The test included five questions that required identifying the area and perimeter of a square and triangles and recognizing angles by using process thinking (application and insight). The scoring of each task was based on the difficulty level: low-level tasks received lower scores (i.e., recognizing types of angles) and high-level tasks received the highest score (i.e., identifying the area and perimeter of a square by using process thinking). The total score for the test was 100. The Cronbach's alpha reliability of this subtest was 0.70.

2.3 Procedures

Mathematical measures and general intelligence tests were administered to the participants in two 50-min sessions. The tests were administered to the participants in small groups of (5–6 students) during school hours in a quiet classroom at school. The students could not use calculators during the mathematical test. School teachers completed the rating scale of students' SRL capabilities after receiving parental approval.

The study was approved by the Ministry of Education's ethical committee. All participants were volunteers and could withdraw from the study at any point. The students and their parents signed informed consent forms.

3 Results

Prior to examining the research questions, we used Shapiro–Wilk tests to determine whether these variables were normally distributed, because the three mathematical tasks had large standard deviations. The results showed that the variables were not normally distributed among both boys and girls ($p < 0.05$). Therefore, we conducted both non-parametric and parametric analyses. The Mann–Whitney test served as the non-parametric analysis to examine the differences

TABLE 2 Mean, SD, and *F*-values of students' general intelligence, SRL, and performance on the three mathematical performance tests, by gender.

	Boys (n = 91)		Girls (n = 79)		*F*-values		
	M	*SD*	*M*	*SD*	*F*	*p*	η_p^2
General intelligence	18.48	3.32	18.47	4.15	0.00	0.979	0.00
SRL	2.40	0.58	2.46	0.58	0.43	0.512	0.00
Operations with numbers	75.33	21.51	69.08	24.26	3.17	0.077	0.02
Geometry	67.84	30.45	57.71	27.82	5.07*	0.026	0.03
Word problems	69.64	21.96	52.44	25.82	22.04***	0.001	0.12

*$p < 0.05$, ***$p < 0.001$; SES, socioeconomic status; SRL, self-regulated learning.

TABLE 3 Pearson correlation coefficients between students' general intelligence, SRL, and performance on the three mathematical tests.

	General intelligence				SRL			
	All sample (N = 170)	Boys (n = 91)	Girls (n = 79)	*Fisher*	All sample (N = 170)	Boys (n = 91)	Girls (n = 79)	*Fisher*
Operations with numbers	0.29***	0.17	0.40***	1.61	0.43***	0.31**	0.57***	2.09*
Geometry	0.40***	0.39***	0.43***	0.31	0.45***	0.54***	0.39***	1.23
Word problems	0.38***	0.29**	0.49***	1.52	0.42***	0.42***	0.51***	0.73

*$p < 0.05$, **$p < 0.01$ ***$p < 0.001$; SES, socioeconomic status; SRL, self-regulated learning.

between boys and girls in each mathematical task. The findings and the significance level of the non-parametric analysis matched the findings of the parametric analysis. Therefore, we presented the findings of the MANOVAs and reported the Means and Standard Deviations instead of the Means and Sum ranks among each gender group. In addition, Levene's test of equality indicated that the assumption of equality of variance was confirmed. Furthermore, multicollinearity testing revealed no multicollinearity problem between the independent variables (the tolerance was greater than 0.1, and VIF was smaller than 10).

In order to examine the first question in the current study regarding whether significant differences would be found between boys and girls in mathematical achievements, one-way MANOVA analysis was conducted. In order to examine the second research question regarding the relations between individual (i.e., general intelligence and SRL) and social (i.e., school SES) factors and the gender gaps in mathematical achievements, first, we examined the correlations between these factors and the students' mathematical achievements. Afterwards, mixed effect modeling analyses (MLM analyses) were conducted to examine the contribution of both individual and social factors to students' mathematical achievements. MLM analyses were conducted since the school is a random factor with students nested by school.

3.1 Gender differences in mathematical achievements in three types of mathematical tasks

Prior to examining the first research question regarding the gender differences in mathematical achievements, the gender differences were examined for the students' performance on general intelligence and their SRL level. No significant gender differences were found in both general intelligence and SRL measures, $F(1,168) = 0.00$, $p = 0.979$, $\eta_p^2 = 0.00$ and $F(1,168) = 0.43$, $p = 0.512$, $\eta_p^2 = 0.00$, respectively. Namely, the students' performance on general intelligence and their SRL level did not differ between boys and girls (Table 2).

In order to examine whether significant differences would be found between boys and girls in the three mathematical tests, one-way MANOVA analysis was conducted. The independent variable was gender, and the dependent variables were the students' performance on the operations with numbers, geometry, and word problems tests. A significant gender difference was found in the performance on the overall score of the combined mathematical test, $F(3,166) = 7.54$, $p < 0.001$, $\eta_p^2 = 0.12$. A separate one-way ANOVA for each mathematical test indicated that boys outperformed girls in word problem solving test and in the geometry test, [$F(1,168) = 22.04$, $p < 0.001$, $\eta_p^2 = 0.12$ and $F(1,168) = 5.07$, $p = 0.026$, $\eta_p^2 = 0.03$, respectively]. The difference between boys and girls in the performance on the operation with numbers test did not reach a level of significance, $F(1,168) = 3.17$, $p = 0.077$, $\eta_p^2 = 0.02$ (see Table 2).

3.2 Relations between individual factors, social factors, and gender differences in mathematical achievements in different types of mathematical tasks

Prior to examining the second research question regarding the relations between individual (i.e., general intelligence and SRL), social (i.e., school SES) factors and gender differences, Pearson correlation analyses were conducted between the students' performance on general intelligence and their SRL level and their performance on the three mathematical tests (see Table 3).

As can be seen in Table 3, the students' performance on the general intelligence test and their SRL level significantly correlated with their performance on the three mathematical tests. In addition, Fisher r-to-z transformation indicated that the correlation coefficient between the students' SRL level and their performance on the operation with numbers test was significantly higher among girls compared to boys (*Fisher* $z = 2.09$, $p = 0.037$). However, Fisher r-to-z transformation indicated that the correlation coefficient of the three mathematical tests and students' general intelligence were not significant.

In order to examine the relations between the individual (general intelligence and SRL), social (school SES), and gender differences in mathematical achievements, we conducted mixed-effect modeling (MLM analysis) using the package lme4 in R. The students' gender, their performance on the general intelligence test, and their SRL level were the fixed factors and the students' level, and SES was the fixed factor at the school level. The school was the random factor, with students nested by school. For each mathematical test, we examined three models. *The zero-model* was conducted to assess the effect size for random effects, which was demonstrated using the ICC value (Lorah, 2018). The zero-model indicated ICC of almost 10% and above, which is considered high enough for MLM to be used. *The first model* examined only the gender differences in each mathematical test, controlling for the school random effect. The results of the first model indicated the same results of the one-way ANOVA analysis, which is presented in this section. This result indicated that boys outperformed girls in the word problem-solving and the geometry tests after controlling for the school random effect. *The second model* examined the effect of all fixed factors (at the student and school levels) on each mathematical test, controlling for the school random effect. The results of the second model regarding gender differences indicated the same results of the ANOVA analysis, according to which boys outperformed girls on the word problem-solving and geometry tests after controlling for the school random effect. Per the results of the Pearson correlation analyses, the students' SRL level significantly correlated with their performance on all three mathematical tests. In addition, the students' performance on the general intelligence test significantly correlated with their performance on the geometry and word problems tests. Finally, the SES of the school significantly correlated with the students' performance on the word problem test, indicating that higher SES schools performed better on the word problem test.

Because we sought to explore the relations between individual (general intelligence and SRL), social (school SES) factors and gender differences, the final model (the third model) examined the interaction effects between these three factors and gender. The results indicated a significant interaction between gender and SRL regarding the students' performance on the geometry test and a significant interaction between gender and SES regarding the students' performance on the word problems test. The significant interaction between gender and SRL indicated that the coefficient of the effect of the students' SRL level on the gender difference in the students' performance on the geometry test increased in accordance with the increase in the SRL level (For 1SD below average in the SRL level: $B = -22.60$, S.E. = 20.21; for average in the SRL level: $B = -32.19$, S.E. = 22.10 and for 1SD above average in the SRL level: $B = -41.78$, S.E. = 24.63). The significant interaction between gender and SES indicated that the coefficient of the effect of the school SES level on the gender difference in the students' performance on the word problems test decreased in accordance with the increase in the school's SES level (For low SES: $B = -43.74$, S.E. = 16.37; for mediocre SES level: $B = -30.90$, S.E. = 17.43 and for high SES level: $B = -18.07$, S.E. = 19.45) (Table 4).

4 Discussion

Scholarly literature offers a plethora of studies on the stereotypic masculine nature of mathematics. This stereotype affects how teachers teach and how well students learn (Steffens and Jelenec, 2011; OECD, 2015). Thus, it is crucial to understand the factors that may lead to gender gaps in mathematics achievement as early as elementary school, as well as how these factors intersect (Ghasemi et al., 2019).

4.1 Gender differences in different mathematical tasks

Our study is unique in that we examined gender differences in various types of mathematical problems and how they are related to individual (i.e., general intelligence and SRL) and social (i.e., school SES) factors among young students. Our results revealed gender differences in elementary school mathematical performance on word problem-solving and geometry tests but not on the operation with numbers test. As we assumed, boys outperformed girls in the word problem-solving and geometry tests. These findings are in line with the variability hypothesis which holds that men represent more variability than women on various psychological constructs. More male variability indicates that often, more boys reach extremely high scores (Stevens and Haidt, 2017). Further studies are needed to explore gender differences in achievements in various types of mathematical tasks among young students.

Our results suggest that boys were similar to girls on operations with numbers tasks. These results corroborate previous studies indicating that girls perform as well as, or better than boys on tests of calculation and arithmetic tasks that require relatively simple cognitive processes (e.g., Hyde et al., 1990; Fennema et al., 1998; Else-Quest et al., 2010; Wei et al., 2012; Räsänen et al., 2021). Our study results support previous conclusions of previous studies that boys and girls are equally equipped with basic numerical competencies, which could assist them in acquiring complex mathematical skills (Hutchison et al., 2019; Räsänen et al., 2021).

As revealed in previous studies (e.g., Kikas et al., 2020), gender differences in students' word problem-solving were also found in our study. Previous studies suggested that the gender disparity in mathematical problem-solving derives from the fact that girls use more concrete strategies that illustrate the problem and represent its solution, while boys occasionally use more abstract strategies, and tend to be more flexible in using strategies for complex and challenging problems compare to girls (Fennema et al., 1998; Zhu, 2007).

In the current study, boys' performance on geometry tasks was greater than girls'. These results corroborate previous studies showing that as boys' visual–spatial ability is better than girls', and that boys usually perform better on geometry tasks (Gilligan et al., 2017; Hutchison et al., 2019). The results of the current study add to the existing literature concerning elementary school children, as most of the previous studies were conducted among junior high and high school children.

4.2 The interrelations between general intelligence, SRL, school SES, and gender differences in mathematical achievements

Our results partly support our second hypothesis that the gender gap increases when the level of school SES increases. The gender

TABLE 4 Results of the mix-linear model (MLM) for students' performance on the mathematical tests.

		Operations with numbers				Geometry				Word problems			
		Model 0	Model I	Model II	Model III	Model 0	Model I	Model II	Model III	Model 0	Model I	Model II	Model III
ICC		0.096	0.090	0.016	0.017	0.165	0.161	0.080	0.081	0.195	0.196	0.055	0.061
Intercept	*B*	72.38***	74.77***	26.22**	45.69***	63.79***	68.15***	−8.51	−17.58	61.87***	69.39***	9.38	24.71*
	S.E.	(3.18)	(3.45)	(8.82)	(12.40)	(5.06)	(9.38)	(11.32)	(15.54)	(4.62)	(4.60)	(8.93)	(12.18)
Gender	*B*		−5.15	−6.36*	−42.97*		−9.38*	−10.66**	10.18		−16.18*	−17.15***	−43.74**
	S.E.		(3.36)	(3.09)	(17.04)		(4.19)	(3.72)	(20.68)		(3.33)	(3.01)	(16.37)
SES	*B*			3.84	0.72			6.10	1.72			7.44*	1.00
	S.E.			(2.68)	(3.49)			(4.53)	(5.25)			(3.28)	(3.91)
General intelligence	*B*			0.58	0.04			1.58**	1.13			1.22**	0.49
	S.E.			(0.47)	(0.73)			(0.57)	(0.89)			(0.46)	(0.70)
SRL	*B*			14.26***	11.69*			17.28***	26.48***			12.57***	14.68***
	S.E.			(3.37)	(4.85)			(4.06)	(5.86)			(3.57)	(4.64)
Gender*SES	*B*				6.17				8.83				12.83**
	S.E.				(4.62)				(5.57)				(4.41)
Gender* General intelligence	*B*				0.88				0.68				1.15
	S.E.				(0.95)				(1.15)				(0.91)
Gender*SRL	*B*				5.74				−17.44*				−3.25
	S.E.				(6.62)				(8.00)				(6.34)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; SES, socioeconomic status; SRL, self-regulated learning.

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differences on word problems are especially prevalent among low SES students. A possible explanation may be related to low SES girls' mathematics self-perception. Previous studies found that girls from high SES have higher mathematics self-perception than girls from low SES (del Río et al., 2019). The results concur with those of other studies (e.g., Penner and Paret, 2008; Wang et al., 2014; Zhu et al., 2018) that reported a strong SES influence on students' mathematical achievements across all age groups. Bessudnov and Makarov's (2015) study showed that boys' advantage in mathematical performance tests was significantly greater in schools of a higher SES, with more advanced curricula. We suggest that future studies further examine the impact of low SES girls' mathematics self-efficacy on their mathematics problem-solving abilities. It seems that the role of gender in students' mathematics learning can be modified when considering societal factors. Furthermore, the results highlight the need for intervention programs in mathematics for girls from low-SES environments, or guidance for parents from low-SES environments. Such early interventions may have profound effects on the children's future development.

Surprising results were found regarding the interactions between gender and SRL regarding geometry tasks. The results indicated that the gender gap increases when the level of SRL increases. It seems that high SRL capabilities assist boys' geometry performance in particular compared to girls'. These results are inconsistent with Bezzina's (2010) study, which suggested that using SRL strategies diminishes gender differences in mathematical performance among high school students. As previous studies suggested that boys usually use fewer SRL strategies during mathematical tasks (Guo et al., 2021), the current study's findings strengthen the existing theoretical knowledge concerning the contribution of SRL capabilities to boys' geometry performance in elementary school and offer valuable information to mathematics teachers that using SRL strategies in geometry tasks could narrow the gap between boys and girls.

The study results revealed no interaction between gender and SES regarding geometry achievements. This contradicts our hypothesis and previous reports on differences between children from low and high SES backgrounds on visual–spatial abilities (Starkey et al., 2004; Levine et al., 2005; Tzuriel and Egozi, 2010; Johnson et al., 2022). The discrepancy can be attributed to the fact that the geometry tasks used in the study were based on the fifth-grade curriculum and did not include mental rotation or highly demanding visual–spatial processing. Future studies should examine the impact of SES on students' performance in geometry using tasks of varied levels of difficulty.

We found that general intelligence contributed to individual differences on word problems and geometry but not on operations with numbers. One possible explanation for this finding is that operations with numbers tasks require only technical procedures and not the higher-order thinking skills posed by word problems and geometry tasks, which also require strategic thinking. Previous research has shown that preschool children's performance in arithmetic computation and word problems was predicted by nonverbal intelligence (Wong and Ho, 2017). However, in another study by Campos et al. (2013) on elementary school children, general cognitive ability was not significant in the regression analysis predicting word problem scores. The authors suggested that selective attention play significant role in solving word problems. Accordingly, we recommend that future studies examine the contribution of working memory, selective attention, and executive functions to student performance on diverse mathematical tasks.

Our study's analyses showed that SRL capabilities contribute to student performance in all mathematical tasks. These results underscore the importance of SRL in determining successful learning experiences in mathematics (Montague, 2008; Rosenzweig et al., 2011; Schunk and Greene, 2018). Previous studies have also suggested that one way to promote mathematical problem-solving is to help students regulate their learning (De Corte et al., 2000; Zimmerman and Schunk, 2011; Desoete and De Craene, 2019; Gidalevich and Kramarski, 2019). Word problem-solving is considered a major obstacle for students as it involves reading comprehension and the activation of various executive function components; that is, to solve word problems, a student must have a conceptual understanding of the problem and then translate the concept into the relevant arithmetical exercise (Lewis and Mayer, 1987; Hegarty et al., 1992; Nortvedt, 2011; Viterbori et al., 2017; Pongsakdi et al., 2020). It seems that students' abilities to plan ahead before starting to solve the problem, choose the right strategy, and self-monitor the solution process are critical for the attainment of high mathematical performance (Mevarech et al., 2018; Kramarski et al., 2021). Because SRL capabilities are still developing at the age of 10 years (about fifth grade; Dignath et al., 2008; Hanin and Van Nieuwenhoven, 2020) and may differ between boys and girls (Heirweg et al., 2019), future studies should further examine the relationship between SRL capabilities and word problem-solving in arithmetic at this age with a larger sample of children.

4.3 Limitations

It is important to recognize some limitations of the current study. First, because only one cohort of seven schools was tested in the current study, it would be interesting to conduct an extended study designed with a large number of children, in which a variety of mathematical abilities are assessed. Second, we were able to assess students' performance across a range of mathematical domains thanks to the utilization of diverse mathematical tasks. However, in order to fully understand gender differences in students' learning strategies during problem-solving in mathematics, it is recommended that future studies use qualitative research tools such as interviews and observations with students.

Furthermore, this study did not examine other factors that impact students' mathematical performance, such as culture, mathematics anxiety, test anxiety, and classroom climate. Although the scope of this paper cannot cover every eventuality, further studies may explore the interrelations between other factors that may relate to elementary students' achievements in various types of mathematical problems.

Finally, in the study, we intentionally used teachers' ratings of students' SRL capabilities and not students' self-report questionnaires to avoid overreliance on student reports. However, it is possible that the teachers' ratings were biased due to prior knowledge of their students' skills and/or anticipated performance. We suggest that future research employ thinking-aloud methods, interviews, and observations to investigate SRL components in different ways. Such methods could support findings concerning the impact of SRL components on mathematical achievement.

4.4 Educational implications

The following educational implications and recommendations on how to modify and narrow the gender gap in mathematics can be inferred from the study's findings: First, we suggest designing an intervention program for in-service educators in mathematics. The program should address the variables leading to gender differences in mathematics. It is recommended that program instructors will collaborate with teachers to devise effective teaching strategies aimed at reducing gender differences in mathematics across various areas of mathematics. Second, seminars and lectures should be designed for parents (especially from a low SES environment). These parental programs should explain the impact of stereotypes on gender differences in mathematics and address the importance of the home environment in reducing gender differences in mathematics, such as playing mathematical games from an early age and engaging young children in mathematical discourse. Third, the current study's findings underscore the importance of providing teachers with guidance to generate a class climate that encourages students to ask questions in class and exposes all students to female role models in STEM disciplines. Furthermore, as mentioned above in the Discussion, the study underscores the necessity of intervention programs in mathematics, adapted to address learning strategies for girls from low SES environments (Russo and Hopkins, 2017; Wang and Degol, 2017). Thus, we recommend the following teaching strategies: teaching mathematics via the lens of a story, providing practical math activities that students can relate to everyday situations, and adopting cooperative learning strategies that enhance confidence in mathematics abilities.

5 Conclusion

Identifying key factors of success plays an important role in efforts to improve academic performance. This study provides new insights related to gender heterogeneity, effective factors and the importance of these factors to ensure gender equality in mathematics achievements. In general, the present study highlights the importance of developing effective learning strategies while solving mathematical tasks. The findings could provide educators and instructional designers with new insights, allowing them to enhance their planning of effective educational programs tailored to improve all students' achievements and narrow the gender gaps in elementary school mathematical performance.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ministry of Education ethical committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

NP-B: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. OS-L: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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