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Gender Differences in High School Students' Beliefs about Mathematical Problem Solving

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Abstract. This study investigated high school students' mathematical problem- solving beliefs based on their gender. A mathematical problem-solving beliefs questionnaire comprising 36 items across six beliefs scales was administered to a sample of 490 students (288 boys and 202 girls) from three schools: a mixed-sex school (106 boys and 103 girls), a single-sex boys' school with 182 students, and a single-sex girls' school with 99 students. The independent samples t-test was used to analyse the effect of gender on high school students' mathematical problem-solving beliefs. Results revealed that there was a significant difference in students' beliefs that some word problems cannot be solved with simple, step-by-step procedures, with girls exhibiting higher beliefs than boys. However, when the entire sample was analysed, gender did not have an overall effect on students' mathematical problem-solving beliefs. It was further revealed that gender did not have a significant effect on students' mathematical problem-solving beliefs at a mixed-sex (boys and girls) school. Results are important for the implementation of a problem-solving approach in a new mathematics curriculum. In addition, the results contribute to the literature in mathematics education by highlighting the importance of gender when considering debates about students' problem-solving beliefs in mathematics.

Keywords: mathematical problem solving; beliefs; high school students; gender

1. Introduction

Beliefs about mathematical problem solving are concerned with an individual's interactions with mathematics subject matter and thereby influence the way the subject is taught and learned in high school classrooms (Marshman, 2021; Simamora & Saragih, 2019). For mathematics students, beliefs have been understood as their implicit or explicit subjective mathematical conceptions that

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are key in shaping their mathematical behaviour (Yin et al., 2020), and predicting performance (Habók et al., 2020; Hidayatullah & Csíkos, 2022). While previous studies investigated problem solving as a skill needed for students to enhance their mathematics abilities (for example NoprianiLubis et al., 2017), this study emanates from the introduction of a new mathematics curriculum in a developing African country, Zambia, in which mathematical problem solving has been identified as one of the key instructional approaches.

As a teaching approach, problem solving has been found to be effective at boosting students' motivation to engage with mathematical problems (Habtamu et al., 2022) and to develop their mathematical abilities (Soebagyo et al., 2022). However, some researchers of this instructional strategy consider it ineffective, partly due to the complex nature of the problem-solving process (Haavold & Sriraman, 2022). In their study about creativity in problem solving, which focused on the role and importance of insight, Haavold and Sriraman (2022) found that unconscious insight emerges as students go through the process of problem solving. They encourage teachers to use problem-solving models that speak to insight as the unconscious processes that occur during problem solving.

We believe that the introduction of the new mathematics curriculum in which problem solving is a key teaching approach opens important lines for research the results of which will contribute significantly to the assessment of the performance of the new mathematics curriculum. This is what the current study is doing. We also think that the new curriculum presents opportunities for teachers to help learners develop skills for confronting problems in their immediate environment by using mathematics.

The rationale for the new curriculum was premised on Zambia's vision for education, summarized in the vision statement "Quality life-long education for all which is accessible, inclusive and relevant to individual, national and global needs and value systems" (MGE, 2013, p. vi). Six teaching methods were identified by the curriculum framers to drive the science, technology, engineering and mathematics (STEM) agenda for mathematics, namely the problem-solving approach (PSA), project method, discovery method, cooperative learning, discussion method, and heuristic method (CDC, 2019, p. 4). The problem-solving approach (PSA) was the focus of this study.

Extensive research has been done on students' gender differences in terms of mathematical problem solving. However, not much research, especially in Zambia, has been conducted on students' gender differences on mathematical problem-solving beliefs. Thus, by investigating gender differences in students' beliefs about mathematical problem solving, this study focused on the newly introduced curriculum which at the time of data collection was in its third year of implementation. The results of this study will act as feedback to teachers and curriculum developers on the newly introduced curriculum. The study purpose was to investigate senior secondary school students' beliefs, with a special focus on gender differences, about problem solving in mathematics, following its introduction in the new curriculum. To accomplish this purpose, the following questions were asked:

1. What is the overall difference between male and female students' mathematical problem-solving beliefs?
2. Is there a significant difference in mathematical problem-solving beliefs between students from a single-sex boys' school and those from a single-sex girls' school)?
3. Is there a significant difference in the mathematical problem-solving beliefs between male and female students at a mixed-sex (boys and girls) school?

2. Literature Review

Several countries in Africa, Asia, Europe, and the United States of America engaged in mathematics curriculum reforms for the purpose of improving the quality of pedagogical strategies and placing mathematics at the centre of finding solutions to problems faced by emphasizing problem solving in mathematics classrooms (Jäder et al., 2020). In Asia, China conducted a reform of the national curriculum to align it with the country's development agenda for the twenty- first century and its expected impact on the education system and policy implementation (Wang et al., 2018). This ensured that mathematics was identified with tools for finding solutions to Chinese problems in classrooms and society. Learners in schools were given opportunities to acquire mathematical skills that would develop them into problem solvers in the wider application of mathematics. In Europe, for example, the Netherlands reformed its mathematics curriculum for 15- to 18-year-old learners which was piloted in schools between 2011 and 2017 (Drijvers et al., 2019). This reform focused on mathematical thinking as its key element. In the USA, examination of a middle-school mathematics curriculum is reported for learners who do not take the same mathematics course (Senk & Thompson, 2020). Curriculum reforms in some Southern African countries like South Africa identified problem solving as one of the key competences that students should have (Department of Education, 2008). This resulted in research outputs in South Africa on the beliefs of prospective teachers related to the nature of mathematics (Spangenberg & Myburgh, 2017), which revealed a significant difference between male and female pre-service teachers.

In all these examples of curriculum reform, there is no focus on students' beliefs about mathematical problem solving. Thus, this study exclusively concentrated on investigating students' mathematical problem-solving beliefs with specific focus on gender differences. Zambia is currently reforming its secondary education mathematics curriculum by aligning the new mathematics curriculum with mathematical problem solving and declaring it as a key activity for teaching and learning. The Curriculum Development Centre (CDC, 2019) emphasized that problem solving would foster critical analysis of mathematical problems for learners and collaboration among teachers through sharing ideas about improvement of their classroom practice. It is believed that the STEM curriculum will provoke creativity, innovativeness and critical thinking among students, thereby enabling them to be problem solvers who are capable of contributing effectively to national development. To realize this, the Zambian Ministry of General Education (MGE) rolled out the implementation of the new STEM

Curriculum in 2019 with the first national examination under this curriculum expected to be written in 2021.

2.1 Problem Solving Approach in Mathematics Teaching and Learning

Problem solving has been identified as a key activity for classroom mathematics teaching and learning experiences across the world (Son et al., 2020). This approach to teaching also has been recognized to best suit mathematics lessons in which the teacher uses learner-centred methods of instruction which are aimed at stimulating students' interest in mathematics, and motivates them to work hard towards improving their mathematical abilities (Ahmed et al., 2020; Irhamna et al., 2020). However, previous research has revealed that despite problem solving being fundamental in developing students' abilities to learning mathematics, they still exhibit difficulties and present errors in their classroom work that involve problem-solving tasks (Son et al., 2019). As problem solving is not a simple and straightforward step-by-step mathematical activity, it is not unusual for students to encounter difficulties in the process of mathematical problem solving (Simamora & Saragih, 2019).

The principal aim with teaching mathematics in secondary school in Zambia and other countries is to train students to be able to solve day-to-day life problems in their immediate environment and beyond, using mathematics (CDC, 2019). To achieve successful problem solving, students are expected to challenge themselves by engaging in high order cognitive processes (He & Wong, 2021). One way in which students can master the mathematical problem-solving process is by using Polya's (1957) problem-solving model (Figure 1). Polya suggests steps through which problem solving can successfully be carried out, namely *understand* the problem, *devise* a solving *plan*, *execute the plan* and *look back*. Figure 1 shows a detailed explanation of each problem-solving step as suggested by Polya.

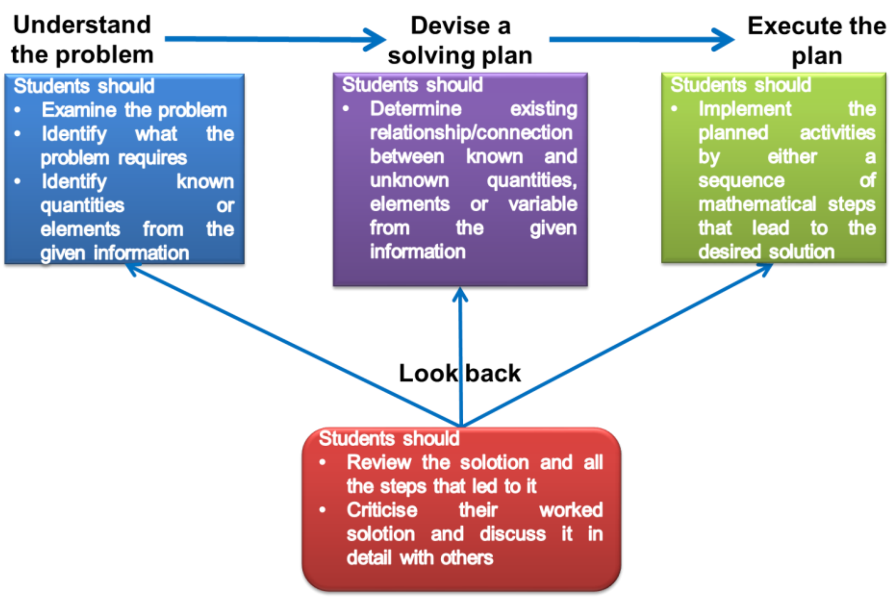

Figure 1. Problem-Solving Model (adapted from Polya, 1957)

In addressing problem solving in teaching and learning, some researchers focused on the teacher (Csíkos & Szitányi, 2020; Ozdemir & Seker, 2021; Tambunan, 2019), while others focused on different aspects of learners (Amalia et al., 2017; Fitriani & Arnawa, 2020; Kholid et al., 2021; LaForce et al., 2017; Lubienski et al., 2021).

Those focusing on teachers, emphasized teachers' development of their own problem-solving skills to enhance their intellectual and cognitive abilities to solve real-life problems as this is the best way in which they effectively could help learners develop problem-solving skills (Ozdemir & Seker, 2021). Teachers' development of individual problem-solving skills should be in tandem with the development of their pedagogical content knowledge (PCK) related to problem solving (Csíkos & Szitányi, 2021). Word problems in mathematics, for example, would require high teacher PCK skills to be taught satisfactorily. It was found in Tambunan's (2019) study that teaching mathematics using the problem-solving strategy improved students' mathematical problem-solving abilities. This implies that teachers whose problem-solving skills and problem-solving PCK are high, are likely to train secondary school students to improve their problem-solving abilities. Teachers' PCK should include good selection of problem posing tasks for their students (Freiman & Fellus, 2021). The use of teaching models has been found to enhance high order problem-solving skills among students and overall mathematical cognitive development (Son, 2020). Alongside these models, teachers can also develop learning devices for students to enhance their problem-solving abilities (Fitriani & Arnawa, 2020), as this can help them in their learning. However, in their study, Fitriani and Arnawa (2020) found that learning devices that had been developed for students were too general and did not facilitate the link to real-life problems, thereby making mathematics instruction meaningless.

Research, focused on school students' problem-solving abilities, has covered different aspects of this topic. Lubienski et al. (2021) investigated gender differences in relation to mathematical problem solving (see Section 2.3 for a detailed discussion), a situation which continues to persist among students, while Kholid et al. (2021) investigated students' reflective thinking and self-efficacy for problem solving. Lubienski et al. (2021) suggest bold problem-solving constructs as a solution to understanding gender disparities in learners' problem-solving skills. The gender and self-efficacy (specifically students' beliefs) variables are subjects of the current study because we think that the gender variable provides a good picture of difficulties faced by male and female students in mathematics, while the beliefs give an insight of how students relate with mathematics. This may increase awareness about gender-specific interventions needed to improve students' problem-solving abilities. To complement teachers' efforts, parents also have a critical role to play in ensuring that they support students at home to develop problem-solving skills regardless of their mathematics orientation levels, because a large number of problem-solving tasks that students are exposed to involve real-life situations (Williams & Williams, 2021). Homework policy in Zambian schools is one of the key policies advocated by the Ministry of General Education. Thus, by helping their children with homework, parents get involved in complementing teachers in inculcating desired problem-solving skills.

As the government of Zambia aligns its mathematics curriculum with STEM principles, it is crucial for teachers to train students how to use technology to solve problems. Through the STEM content they receive in their classrooms, Zambian students are given opportunities to develop their abilities to use mathematics content and practices to communicate their designed solutions to problems. This is critical for the realization of the STEM curriculum objectives (Shanta & Wells, 2020). Some researchers found the problem-based learning (PBL) approach through the use of PBL models as effective when teaching (Amalia et al., 2017; LaForce et al., 2017; Simamora et al., 2017). They posited that PBL could help in improving students' problem-solving skills and has potential to improve students' attitudes, beliefs and motivation levels to take up STEM careers in future. For Zambia, whose citizens come from strong cultural backgrounds, development of teaching/learning materials for use during lessons should be done with full consideration of students' cultural context. Teaching and learning materials can be developed by integrating and adapting local materials that students interact with every day, like artifacts (Simamora & Saragih, 2019). This is because the integration of the local culture will demystify mathematics from being regarded as unpractical, abstract and foreign.

One of the aims of the STEM curriculum being implemented in Zambia is inclusive mathematics (CDC, 2019). This implies that students with disabilities should be adequately given opportunities to develop their problem-solving skills like any other student. Some researchers have studied the improvement of the problem-solving abilities of students with disabilities (Root et al., 2021; Spooner et al., 2017) using both school-based and real-world mathematics tasks. This has proven to be effective.

2.2 High School Students' Beliefs About Problem Solving

Secondary school students' beliefs about mathematics in general and mathematical problem solving in particular, affect their level of interest in the subject, and whether or not they are motivated to learn it and take up mathematics-related courses at university (Hidayatullah & Csíkos, 2022; Humairah, 2021; Jusra & Ramadhani, 2022). To excel in mathematics, students need to apply themselves to the subject by putting in much effort, as well as being persistent in their studies. Research has shown that students' beliefs about mathematics have a significant effect on their persistence to learn new concepts and the effort they apply (Concha Zelada et al., 2019; Keleş, 2022; Sholihah et al., 2022; Sokić et al., 2021). It has also been observed that students' beliefs about mathematics are usually false with a perception that the subject is difficult and boring (Hamukwaya & Haser, 2021).

Students' beliefs have also been found to influence their critical thinking, conceptualization, recognition of mathematical problems and engagement in problem solving (Belecina & Ocampo, 2018). Thus, their beliefs can significantly guide and develop their critical thinking as they engage in problem-solving activities. Activities selected for problem solving must be supported by context-rich curricula like the STEM mathematics curriculum that has been developed in Zambia (Gijsbers et al., 2020; Peranginangin et al., 2019). Allowing students to work on their tasks in small groups and using suitable strategies of teaching would enhance their beliefs about mathematical problem solving (Ajan Jr et al., 2021). It has been observed that students taught by teachers that favoured the problem-solving approach enhanced their problem-solving skills, reasoning and creativity more than those taught by teachers who favoured other teaching approaches (Tambunan, 2019).

Development of learning and teaching materials should always accompany new curricula because it helps teachers and students not to lose focus on the subject matter demands of the curriculum. Unfortunately for Zambia, there seems to be no teaching and learning materials in schools to support the STEM curriculum. Teachers and students are depending on materials developed before curriculum reforms to align teaching and learning to STEM principles. Student textbooks and worksheets have a significant effect on the development of students' problem-solving skills (Jäder et al., 2020; Ulandari et al., 2019). This is because teachers mainly use textbooks to prepare lesson plans, and students depend largely on textbooks for their studies. Through reading textbooks, students' beliefs about mathematical problem solving can improve. Textbooks can improve students' mathematical word problem solving (Sahendra et al., 2018), as mathematical representations enhance problem-solving skills by acting as mediators between students' beliefs and mathematical problem solving (Yuanita et al., 2018).

In several other studies high school students' beliefs about mathematical problem solving have been investigated, reaching consensus that positive beliefs are essential for enhanced problem-solving skills of students (NoprianiLubis et al., 2017; Özcan & Eren Gümüş, 2019; Prendergast et al., 2018; Surya & Putri, 2017; Zulnaidi et al., 2021) with others focusing on the effect of gender (Awofala, 2017), while some focused on repercussions on motivation (Rojo Robas et al., 2020). Thus, the purpose of this paper was to investigate high school students' mathematical problem-solving beliefs based on their gender. To accomplish this purpose, the study sought answers to the following questions.

2.3 High School Students' Problem-Solving Beliefs Based on Gender

The gender gap in mathematical performance of male and female students has consistently emerged to be a topical issue among mathematics education researchers (Dai et al., 2022; Mejía-Rodríguez et al., 2021). Several varied reasons have dominated debates among experts in explaining this status quo. It has been reported that the gender divide continues into tertiary education where entrants with high mathematical competences from high school show high levels of solving mathematical problems regardless of their gender (Widiyasari et al., 2022). The gender gap has been attributed largely to attitudes toward mathematics and different mathematical abilities between the two genders (Mejía-Rodríguez et al., 2021). For example, Mejía-Rodríguez et al. (2021) argued that in many countries, including Zambia, boys tend to exhibit superior performance when solving mathematical problems across all mathematics topics. To reduce the gender divide in students' mathematical performance, Dai et al. (2022) shared empirical evidence which suggests that mathematical activities that incorporate the use of games and narratives tend to support girls' mathematical problem-solving skills development.

Considering that creativity is important in problem solving, several studies reported mixed results related to gender differences in students' creativity when solving mathematical problems (He & Wong, 2021; Keleş, 2022; Sokić et al., 2021; Taylor & Barbot, 2021). In their study, He and Wong (2021) found that boys demonstrated more creativity in their problem-solving activities than girls. This result agrees with the findings of Mejía-Rodríguez et al. (2021). In contrast to this result, Sholihah et al. (2022) in their study related to the effect of gender on students' creative problem-solving abilities, found that girls scored higher than boys. In another study, Keleş. (2022) and Concha Zelada et al. (2019) found that gender did not affect students' creativity when engaging in problem solving. These results indicate that research about gender differences in students' problem solving has continued to produce results that are not consistent. This is the reason for continued and growing research into this phenomenon in different contexts.

Research has also shown the effect of gender on students' mathematical problem-solving self-efficacy (e.g., Imaroh et al., 2021; Jusra & Ramadhani, 2022; Subekti & Krisdiani, 2021; Wijayanti et al., 2021). These studies posit that students with high self-efficacy, whether they are boys or girls, tend to exhibit higher mathematical problem-solving abilities. Jusra and Ramadhani (2022), and Subekti and Krisdiani (2021) in their studies found that girls exhibited higher problem-solving abilities than boys, owing to their high self-efficacy. In these studies girls showed high confidence and were motivated to tackle difficult mathematical problems. Contrary to the above findings, Kasturi et al. (2021) in their study about gender-based differences in students' mathematical problem-solving self-efficacy found that there was no difference between the two groups based on gender.

Mathematical beliefs also have been found to play a fundamental role in students' mathematical problem solving related to word problems (Hidayatullah & Csíkos, 2022; Humairah, 2021). In his study, Humairah (2021) found that in terms of mathematical problem solving concerned with word problems, mathematical reasoning and abilities of girls were superior to that of boys. This result implies that girls were more confident and motivated to tackle word problems. This is important because it demonstrates that in some cases girls have better mathematical abilities than boys.

3. Methodology

A quantitative research design, using a cross-sectional survey method underpinned this study. A single, once-off, cross-sectional survey was administered to a convenient sample of high school students. The survey focused on high school students' beliefs about mathematical problem solving. The research design is shown in Figure 2.

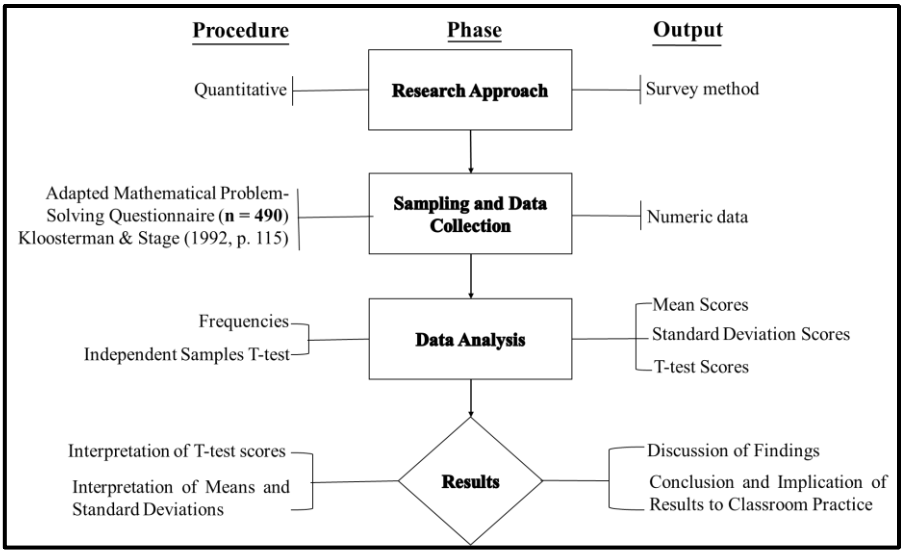

Figure 2. Visual Representation of the Research Design

3.1 Participants

Participants consisted of Grade 12 students aged between 15 and 18 years who were selected from three public secondary schools in the Eastern Province of Zambia. At the time of data collection, it was established that these students were following the newly introduced STEM mathematics curriculum and were expected to be examined based on the new curriculum. Cluster sampling – a probabilistic sampling technique, was used to select three schools in which each school was regarded a cluster. This technique was preferred because of the geographical spread of the schools in the district. All Grade 12 students in each cluster were requested to participate in the study. However, only a total of 490 students (288 boys and 202 girls) from three schools volunteered to participate. Of these, 209 students (106 boys and 103 girls) were drawn from a mixed-sex school, 182 from a single-sex boys' school and 99 from a single-sex girls' schools. The rationale for selecting a mixed-sex school and two single-sex schools was premised on the purpose of the study which included testing the effect of gender on students' mathematical problem-solving beliefs. Grade 12 students were selected because they had followed the STEM curriculum for more than one year, thus, it was assumed that their mathematical problem-solving beliefs would be more representative of all senior secondary school students in the population of the Eastern Province.

3.2 Research Procedure

Data were collected from students at three different high schools over a period of three consecutive days. At each of the schools an appointment was made for students to participate in the study outside learning hours so as not to disrupt their time-tabled lessons. Thus, the data collection took place during prep time. Students were assured that their participation in the study would have no consequences for their scores in the continuous assessment tests or the final examinations at the end of the year, because the study was purely about gathering their ideas and beliefs about mathematical problem solving with the aim of improving the teaching and learning of mathematics. Thus, they were requested to provide honest responses. At each school, students were asked to indicate their level of agreement with each statement in the questionnaire by rating the items from *(1*) strongly disagree to (5) strongly agree. This exercise took place in their respective classrooms. They completed the questionnaires in 45-50 minutes.

3.3 Instruments

The data collection instrument used in this study was a survey adopted from Kloosterman and Stage (1992, p. 115), and was developed to measure students' mathematical problem-solving beliefs. The survey consisted of 36 items on a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree. The items were evenly sub-divided into six beliefs (see Appendix 1). The items thus were distributed across six scales (beliefs). The Cronbach's alpha values for each scale were calculated and found to be in the range 0.71 to 0.78. Thus, the questionnaire was reliable and suitable for use in this study.

3.4 Data Analysis

The data set for the study consisted of 490 completed questionnaires. We employed the Statistical Package for Social Sciences version 23 (SPSS23) for analysing the survey data. To accomplish the purpose of the study, descriptive statistics and the independent samples t-test were used to answer the posed research questions. The independent samples t-test was conducted to compare their mathematical problem-solving beliefs by gender. In doing so, we focused on the mean scores and standard deviations, which helped us to analyse differences in self-perceived mathematical problem- solving beliefs of secondary school students based on their gender.

4. Results

With the purpose of investigating gender differences in high school students' beliefs about mathematical problem solving, this section presents the findings together with a brief discussion of each result. For easy reading, results are presented according to research questions.

RQ1. What is the overall difference between male and female students' mathematical problem-solving beliefs?

To answer this question, participants from the three schools were assigned to two groups, namely a male and a female group. The independent samples t-text was then conducted to analyse differences in participants' mathematical problem-solving beliefs. For each of the six beliefs (see Table 2), there were differences in mean scores based on gender, although the differences were not statistically significant. This could be verified from the p-values that all are greater than 0.05 (see Table 2). The test for the assumption of equal variances for male and female participants also was conducted, using the Levene's Test for Equality of Variances. Results for the homogeneity of variances shows that p-values for all the t-tests were in the range p = 0.2 to p = 0.7. This implies that the assumption for homogeneity of variances was not violated.

When Table 1 is analysed, it was found that female participants believed more than males that they could solve mathematical problems that are time-consuming ($\bar{X}_{\text{male}}=3.06 < \bar{X}_{\text{female}}=3.08$), and that some mathematical word problems cannot be solved by merely using simple steps ($\bar{X}_{\text{male}}=3.52 < \bar{X}_{\text{female}}=3.59$). They also believed more than male participants that mathematics as a subject is very useful in the daily life of every individual ($\bar{X}_{male}$=2.96 < $\bar{X}_{female}$=2.98), and that one can increase his/her mathematical ability when much effort is applied during studies ($\bar{X}_{male}$=4.37 < $\bar{X}_{female}$=4.41). However, while male participants had low beliefs that some word problems could easily be solved by following simple mathematical steps or procedures, they believed more than females that word problems are important in mathematics ($\bar{X}_{male}$=2.93 > $\bar{X}_{female}$=2.84), and that conceptual understanding is important in mathematics ($\bar{X}_{male}$=3.18 > $\bar{X}_{female}$=3.16).

Table 1. Overall difference in male and female students' mathematical problem-solving beliefs

Belief	Gender	N	$\bar{X}$	SD	Df	T	Sig
Belief 1: Solving mathematics problems that are time-consuming	Male	288	3.06	.61	487	-.49	.626
	Female	202	3.08	.67	487		
Belief 2: Word problems that cannot be solved using simple procedural steps	Male	288	3.52	.49	487	1.61	.108
	Female	202	3.59	.49	487		
Belief 3: Importance of conceptual understanding in mathematics	Male	288	3.18	.54	487	.47	.640
	Female	202	3.16	.59	487		
Belief 4: Importance of word problems in mathematics	Male	288	2.93	.64	487	1.58	.115
	Female	202	2.84	.63	487		
Belief 5: Effort and mathematical ability	Male	288	4.37	.65	487	-.59	.551
	Female	202	4.41	.63	487		
Belief 6: Usefulness of mathematics	Male	288	2.96	.49	487	-.39	.697
	Female	202	2.98	.42	487		

RQ2. Is there a significant difference in mathematical problem-solving beliefs between students from a single-sex boys' school and those from a single-sex girls' school?

We also compared mathematical problem-solving beliefs of students from the two single-sex schools. We wanted to find out whether girls' beliefs are different from those of boys when they learn on their own and interact academically among themselves at school. It is important to understand whether girls or boys have strong beliefs that they can do mathematics without the influence of the other gender.

The independent samples t-test showed that there was a statistically significant difference between male and female students' beliefs that some word problems could not be solved using simple mathematical steps [t(279) = -2.39, p = .018]. Female students believed more than their male counterparts ($\bar{X}_{male}$ = 3.49 < $\bar{X}_{female}$ = 3.63) that there are word problems in mathematics that cannot be solved using simple mathematical steps or procedures (see Table 1). However, there were no statistically significant differences in the other five beliefs with p-values ranging from 0.199 to 0.932 (see Table 2). Even though there were no significant differences about these beliefs, small mean differences were recorded regarding some beliefs which provided insight into characteristics of the two groups' gender differences. Male participants posted higher ratings than females in their belief that conceptual understanding in mathematics is important ($\bar{X}_{\text{male}}$ = 3.19 > $\bar{X}_{\text{female}}$ = 3.14) and that word problems are also important in mathematics ($\bar{X}_{\text{male}}$=2.91 > $\bar{X}_{\text{female}}$ = 2.82). Female participants, on the other hand, believed more than their male colleagues that effort is required for one to increase one's mathematical ability ($\bar{X}_{\text{male}}$ = 4.44 < $\bar{X}_{\text{female}}$ = 4.47) and that mathematics is useful in the daily lives of humans ($\bar{X}_{\text{male}}$ = 2.91 < $\bar{X}_{\text{female}}$ = 2.98).

Table 2. Difference regarding mathematical problem-solving beliefs in male and female students from single-sex schools

Belief	Gender	N	$\bar{X}$	SD	Df	T	Sig
Belief 1: Solving mathematics problems that are time-consuming	Male	182	3.01	.63	279	.09	.932
	Female	99	3.01	.66	279		
Belief 2: Word problems that cannot be solved using simple procedural steps	Male	182	3.49	.49	279	-2.39	.018
	Female	99	3.63	.47	279		
Belief 3: Importance of conceptual understanding in mathematics	Male	182	3.19	.54	279	.63	.530
	Female	99	3.14	.58	279		
Belief 4: Importance of word problems in mathematics	Male	182	2.91	.62	279	1.16	.245
	Female	99	2.82	.64	279		
Belief 5: Effort and mathematical ability	Male	182	4.44	.61	279	-.36	.719
	Female	99	4.47	.62	279		
Belief 6: Usefulness of mathematics	Male	182	2.91	.45	279	-1.29	.199
	Female	99	2.98	.47	279		

RQ3. Is there a significant difference in the mathematical problem-solving beliefs between male and female students at a mixed sex (boys and girls) school?

We further analysed gender differences between male and female participants at a mixed-sex school where girls and boys attended mathematics lessons in the same class and possibly influenced each other's belief systems in relation to the subject. Results of the independent samples t-text showed no statistically significant differences in participants' beliefs about mathematical problem solving. To appreciate any small gender differences, we base our analysis on the mean scores recorded by the two groups.

Examining Table 3, it is found that female participants believed more than males that they could solve mathematical problems that are time-consuming ($\bar{X}_{male} = 3.13 < \bar{X}_{female} = 3.16$) and that effort can increase one's mathematical ability ($\bar{X}_{male} = 4.26 < \bar{X}_{female} = 4.35$). Male participants had higher mean scores than females in their beliefs that some word problems cannot be solved using simple, step-by-step procedures ($\bar{X}_{male} = 3.58 < \bar{X}_{female} = 3.56$), and that word problems are useful in mathematics ($\bar{X}_{male} = 2.96 > \bar{X}_{female} = 2.86$). They also believed more than females that mathematics is useful in one's daily life ($\bar{X}_{male} = 3.05 > \bar{X}_{female} = 2.97$).

Table 3. Difference in male and female students' mathematical problem-solving beliefs in a mixed-sex school

Belief	Gender	N	$\bar{X}$	SD	Df	T	Sig
Belief 1: Solving mathematics problems that are time-consuming	Male	106	3.13	.56	206	-.35	.730
	Female	103	3.16	.67	206		
Belief 2: Word problems that cannot be solved using simple procedural steps	Male	106	3.58	.47	206	.34	.735
	Female	103	3.56	.50	206		
Belief 3: Importance of conceptual understanding in mathematics	Male	106	3.18	.55	206	.05	.957
	Female	103	3.18	.61	206		
Belief 4: Importance of word problems in mathematics	Male	106	2.96	.67	206	1.19	.237
	Female	103	2.86	.61	206		
Belief 5: Effort and mathematical ability	Male	106	4.26	.69	206	-.99	.324
	Female	103	4.35	.64	206		
Belief 6: Usefulness of mathematics	Male	106	3.05	.54	206	1.21	.228
	Female	103	2.97	.35	206		

5. Discussion

This discussion will take place at three levels. We first discuss gender differences when the entire sample is divided into two groups of male and female, then we consider a sub-sample of male and female students from single-sex boys' and girls' schools respectively. Finally, we delve into gender differences for male and female participants from a mixed-sex school. This allowed us to search deeply for gender differences in participants' beliefs, if any.

When the entire sample was divided into two groups of male and female participants, it was found that there were no significant gender differences in the mathematical problem-solving beliefs of participants across all six beliefs. This implies that, in general, gender does not have statistically significant effects on secondary school students' mathematical problem-solving beliefs. Thus, their mathematical abilities would not be impacted by their beliefs. This result is not consistent with findings of Kasturi et al. (2021), as well as Subekti and Krisdiani

(2021), who reported significant differences between male and female students' attitudes towards mathematical problem solving. The result of this study has implications for mathematics teachers' lesson planning when they choose to employ problem solving as a preferred teaching method.

They will not need to consider gender differences as they plan for classroom instruction. In addition, it is worth noting that the robust t-test in the current study found no significant gender differences in students' beliefs about time consuming mathematical problems, problems related to usefulness of mathematics in one's daily life, and mathematical problems that cannot be solved by using routine step-by-step procedures. A literature check showed that some studies also did not find statistically significant differences by gender in students' problem-solving beliefs (e.g., Kasturi et al., 2021).

We also were interested in finding out if significant gender differences in this regard could be found between females from a girls' school and males from a boys' school. It would be interesting to understand the belief system of a group of either male or female students who were not mathematically influenced by the other gender. Results of this study showed that there was a significant difference in students' beliefs about mathematical problems that can be solved using a step-by-step procedure, with females in the majority when the analysis was based on gender. This result is consistent with the findings of Humairah (2021), whose study found superior problem-solving abilities among girls when compared to boys. However, gender did not significantly affect students' other five beliefs. Similarly, when the analysis considered only participants at a mixed-sex school, no significant gender differences were found. This means that gender should not affect teachers' planning for students.

Finally, understanding students' beliefs is important for teachers' instructional planning. It is argued that students who consider problem solving a difficult task usually are more likely to view it as a short process that could be accomplished by memorizing rules and procedures (Hamukwaya & Haser, 2021). When students exhibit positive beliefs about problem solving, they would more likely invest in fully understanding the problem and planning the strategy for getting to the answer before attempting to solve it (Rahmah & Saputro, 2021). Teachers could also support improvement of students' problem-solving beliefs and abilities when they use problem-based methods in their instruction (Bosica et al., 2021). In cases where there were no statistically significant gender differences, this could mean that students' beliefs about mathematical problem solving do not significantly contribute to their performance in class and in national examinations.

6. Conclusion

The purpose of this study was to investigate high school students' mathematical problem-solving beliefs based on their gender. This study was conducted at a time when Zambia was reforming its curriculum to align it with STEM principles. It makes a significant contribution to theory and practice by highlighting how gender can/cannot influence students' beliefs about mathematical problem solving. Gender differences in relation to students' mathematical problem-solving beliefs have not been extensively studied in the Zambian context. Thus, results of this study make a new and original contribution in this regard, considering that the study acts as a response to curriculum reforms being implemented in Zambia.

It was assumed by the authors that reforming a curriculum presented opportunities for the education system in Zambia to respond to society's needs, whose problems would require solutions anchored in mathematical knowledge, while implementing those solutions would come with some challenges. One such challenge would be students' beliefs, because these beliefs would determine the acceptability of the new curriculum. Considering that problem solving has been identified as one of the key instructional methods in the new curriculum, it is important for teachers to understand students' beliefs as they are crucial in the successful implementation of the curriculum and student academic achievement. This work is useful as it provides information on how problem solving as a teaching strategy can be improved, especially when students' beliefs are considered. The study is also useful to policy makers for planning purposes. At the planning stage of a curriculum implementation process, students' beliefs, and the potential challenges they pose, should be taken care of seriously .

This study opens some interesting lanes for future research. Researchers might consider conducting future studies using mixed-methods research that includes interviews with participants in order to gain a deeper understanding of students' mathematical problem-solving beliefs. It would also be insightful for future researchers to consider investigating students' attitudes and beliefs about mathematical problem solving by examining how the two relate. Lastly, it would be insightful for future studies to consider a longitudinal study on students' mathematical problem-solving beliefs by studying a cohort from Grade 10 through to Grade 12 for a period of three years. Such a three-year study might produce interesting results for theory, practice, and policy.

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Appendix 1

Mathematical Problem-Solving Beliefs Questionnaire
(Adopted from Kloosterman, P. & Stage, F. K., 1992)

Dear student

Please fill in the questionnaire below by indicating with a cross (X) how you agree / disagree with the given statements. Please be very honest. Participation is voluntary and all answers will be treated anonymously. Do not write your name on the questionnaire. Your participation in this research is appreciated.

SCHOOL:…………… GENDER:………… GRADE:………. AGE:……

I can solve time-consuming mathematics problems		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
1	Math problems that take a long time don't bother me					
2	I feel I can do math problems that take a long time to compute					
3	I find I can do hard math problems if I just hang in there					
4	If I can't do a math problem in a few minutes, I probably can't do it at all					
5	If I can't solve a math problem quickly, I quit trying					
6	I'm not very good at solving math problems that take a while to figure out					
There are word problems that cannot be solved with simple, step-by-step procedures		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
7	There are word problems that just can't be solved by following a predetermined sequence of steps					
8	Word problems can be solved without remembering formulas					
9	Memorizing steps is not very useful for learning to solve word problems					
10	Any word problems can be solved if you know the right steps to follow					
11	Most word problems can be solved by using the correct step-by-step procedure					
12	Learning to do word problems is mostly a matter					

	of memorizing the right steps to follow					
Understanding concepts is important in mathematics		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
13	Time to investigate why a solution to a math problem works is time well spent					
14	A person who doesn't understand why an answer to a math problem is correct hasn't really solved the problem					
15	In addition to getting a right answer in mathematics, it is important to understand why the answer is correct					
16	It's not important to understand why a mathematical procedure works as long as it gives a correct answer					
17	Getting a right answer in math is more important than understanding why the answer works					
18	It doesn't really matter if you understand a math problem if you can get the right answer					
Word problems are important in mathematics		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
19	A person who can't solve word problems can't really do maths					
20	Computational skills are of little value if you can't use them to solve word problems					
21	Computational skills are useless if you can't apply them to real-life situations					
22	Learning computational skills is more important than learning to solve word problems					
23	Math classes should not emphasize word problems					
24	Word problems are not a very important part of mathematics					
Effort can increase mathematical ability		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
25	By trying hard, one can become smarter in maths					

26	Working can improve one's ability in mathematics					
27	I can get smarter in maths by trying hard					
28	Ability in maths increases when one studies hard					
29	Hard work can increase one's ability to do maths					
30	I can get smarter in maths if I try hard					
Mathematics is useful in daily life		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
31	I study mathematics because I know how useful it is					
32	Knowing mathematics will help me earn a living					
33	Mathematics is a worthwhile and necessary subject					
34	Mathematics will not be important to me in my life's work					
35	Mathematics is of no relevance to my life					
36	Studying mathematics is a waste of time					