Northwest Journal of Teacher Education

Volume 10
Issue 1 *Northwest Passage: Journal of Educational Practices*

Article 2

January 2012

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Recommended Citation
Nejad, Masomeh Jamshid (2012) "Secondary school students' lack of mathematics understanding," *Northwest Journal of Teacher Education*: Vol. 10 : Iss. 1 , Article 2.
DOI: https://doi.org/10.15760/nwjte.2012.10.1.2

Secondary school students' lack of mathematics understanding

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Abstract

A study was conducted to investigate the influence of pupils' beliefs on their performance in problem solving. Twenty-seven students from Grade 8 participated in this study. The findings showed that there is a positive correlation between participants' belief, some subscales of belief and participants' performance in problem solving. Further research was then suggested.

Introduction

According to the National Council of Teachers of Mathematics (2000), students are not going to become logical thinkers, and therefore be successful in today's society, without learning through problem solving. Problem solving is a skill enabling students to understand, apply, and synthesize knowledge they have previously learned (Schoenfeld, 2002). Learning to solve problems seems to be a reason for pupils study mathematics; in fact, learning mathematics should prepare them to solve problems in their life (NCTM, 2002).

In order to achieve a better understanding of students' performance in mathematical problem solving, scholars investigated the crucial role of affective factors such as beliefs, attitudes and values on students' performance (McLeod & McLeod, 2003). Schommer-Aikins, Duell, and Hutter (2005) have found that students hold a number of different beliefs about mathematics, which affect the way they deal with mathematical situations. Recently, researchers have also investigated the interrelation between students' mathematical performance and beliefs in mathematical problem solving, mathematical competency, learning and social context (Schuck & Grootenboer, 2004; Grootenboer & Hemmings, 2007). It is widely accepted that students' mathematical beliefs, a system of one's mathematical world view constructed by students' experience in the classroom (Schoenfeld, 1985), have significant effects on their overall achievements of mathematical learning and problem solving (Seegers & Boekaerts, 1993; Vermeer, 1997; DeCorte, Verschaffel & Op't Eynde, 2000). However, "the relationship between students' beliefs and learning in mathematical problem solving is not simple, linear and unidirectional; rather it is complex and intricate" (Tarmizi & Tarmizi, 2010, p.4703). Knowing this, it seems important to pay close attention to affective factors and their impacts on students' performance in mathematical learning and problem solving. The goal of this study is to investigate students' beliefs in relation to their performance in mathematical problem solving.

Problem solving in Mathematics

In today's rapidly changing society, problems are a constant part of life. Many times the problems have multidimensional aspects and people require skills to solve them. Currently, problem identification, reasoning, mathematical ideas and critical thinking are seen as general skills for many job-seekers (Swanson & Sachs- Lee, 2001).

For more than three decades, problem solving has been identified as "the focus of school mathematics" (Schoenfeld, 1987) "at all grade levels" (Schoenfeld, 2002, p. 15). Historically, problem solving appears to have been valued as a goal to intellectual development, as a skill to be taught, and as a method of teaching for many years (Eves, 1964). Polya, in 1945, was one of the first scholars to propose a set of simple steps (understanding the problem, devising a plan, carrying out the plan, and looking back) for teaching problem solving as a skill in mathematics. However, the precise place occupied by problem solving within the discipline has changed since this time. The National Council of Supervisors of Mathematics (NCSM) declared, in 1978, that problem solving should be positioned at the center of mathematics education (Schoenfeld, 1992).

In 1989, NCTM issued Curriculum and Evaluation Standards for School Mathematics, and called for significant changes in the current curriculum to shift the emphasis towards process instead of content and skills through applying problem solving to all grade levels (Schoenfeld, 2002, p. 15). The California Mathematics Conceptual Framework also emphasized problem solving as one of main principles in teaching and learning mathematics (California Department of Education, 2006). As such, implementing problem solving in mathematics classes becomes popular in many of USA states (Tuska, 2003) and some other countries such as Canada and China.

To a student of mathematics, a problem can be defined as a situation in which there is a mathematical question whose solution is not immediately accessible to the solver (Schoenfeld, 1989). Problem solving involves “the use of problems where the solution or goal is not immediately attainable and there is no obvious algorithm for the students to use” (McLeod, 1988, p. 135). Problem solving, as a complex behavior, has been considered as one of the most important aspects of cognitive development for adolescents (Swanson & Sachs- Lee, 2001). Furthermore, it has been seen as an important component in math education enabling students not only to solve math problems but also to transfer their knowledge to other situations (NCTM, 2000). Indeed, the NCTM (2002) has highlighted the ever-increasing importance of problem solving as a skill for students’ everyday life (p. 3). The next section will review some influential studies about students’ beliefs in mathematics.

Students’ Beliefs in Mathematics

From the mathematical point of view, beliefs are generated through pupils’ involvement in the mathematics classroom (Schoenfeld, 1985). Students’ beliefs could include students’ views about mathematical competency, motivational factors, their learning context, and even about social context. Conducting a research aiming students’ beliefs amongst a group of 230 high school students in New York, Schoenfeld (1989) found that students believe that they can master the subject if they work at it. Students also believe that one needs mathematics to think logically (ibid, p. 348). However, they also hold that “mathematics is mostly memorizing” (p. 338). Investigating the possible justification for this belief, Schoenfeld (1989) observed that the problems worked out in class could be mostly solved by the direct application of a step-by-step procedure students had already learned. Rarely, if ever, did the teacher expose them to problems for which there was not a rule at hand. Students’ beliefs about memorizing as the best way of learning mathematics prompted Schoenfeld (1989) to warn other scholars about the lack of real application problems in mathematics classroom.

Another influential study was the Kloosterman and Cougan’s (1994) research involving mathematical beliefs, which studied 62 students from grade one to six. All participants were from the same school taking part in the second year of a project aimed at the improvement of mathematical instruction through problem solving. In order to obtain a better understanding of

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DOI: 10.15760/nwjte.2012.10.1.2

elementary students' beliefs and attitude toward mathematics, the following five categories of beliefs were studied: (1) the extent to which students like mathematics, (2) the perceived parental support of mathematics, (3) the perceived usefulness of mathematics, (4) the self-confidence in learning mathematics, and (5) the existence of an inherent mathematical ability. The results suggested that most of the students believed that mathematics is useful and everyone has the ability to learn it if they invest sufficient effort. However, Kloosterman and Cougan (1994) indicated that the setting of school may have an impact on their results as the schools have had a fairly strong mathematics program which may have compromised their results. Therefore, the researchers interpreted the results "in terms of the effects that good instruction can have on beliefs" (p. 386).

Kloosterman, Raymond and Emenaker (1996) conducted a three-year research project on elementary students' beliefs about their learning and doing mathematics. They found that students have the following opinions: a narrow perspective on the usefulness of mathematics, a fairly accurate meaning of their own achievement, and a tendency to like mathematics more as it became harder.

Choosing successful mathematics students, Carlson (1999) conducted a study from a different perspective; she collected both qualitative and quantitative data on the beliefs of 34 successful mathematics graduate students at a large university. For her qualitative analysis, Carlson (1999) interviewed six successful graduate students who had completed, and received an A in, at least one graduate level mathematics class. She observed the following three themes in her analysis: (1) all six successful students had confidence in their ability to work through problems, (2) they were keen to deal with mathematical problems even after spending long periods of time on each problem, and (3) they liked being challenged by complex mathematical tasks. Analyzing her quantitative data, Carlson (1999) found that persistence is a necessary trait for success in mathematics classes. Finally, she suggested that students require exposure to challenging problems early on with assistance from a teacher when the students need it.

Generally, scholars agree that students hold a number of different beliefs about mathematics; and some students have a very narrow set of mathematical beliefs (Frank, 1985; Kloosterman, Raymond & Emenaker, 1996). Furthermore, "mathematics requires time and effort", and "mathematics is useful" have been seen as two most common beliefs (Kloosterman & Cougan, 1994; Schoenfeld, 1989; Schommer-Aikins, Duell, & Hutter, 2005). Finally, a group of students believe that learning mathematics is merely memorizing some rules and performing set procedurals (Frank, 1985).

The influence of Beliefs on Students' Performances

In addition to the description of students' mathematical beliefs, researchers have shown an increased interest in studying the role of beliefs on students' mathematical performance (Schuck & Grootenboer, 2004; Leder & Forgasz, 2006; Grootenboer & Hemmings, 2007). During the 1980s, the crucial domains that limited students' performance on solving the problems attracted the researchers' attention (Schoenfeld, 1985). Students' beliefs have been identified as a significant factor influencing their performance in problem solving (McLeod & Adams, 1989; McLeod, 1992, McLeod, 1997). Substantial progress in researching the role of beliefs in students' performance in mathematics has been made by the work of Schoenfeld (1985), Purvis (2000), and McLeod & McLeod (2003). Throughout some early research into problem solving, Schoenfeld (1985) highlighted the effect of students' perception on their performance by stating that '…. students problem solving performance … is a function of their perceptions of that their experiences with mathematics (Schoenfeeld ,1989 p. 349). Purvis (2000) also by categorizing middle school students according to their sentiment to mathematics (negative, positive, or neutral) and calculating the academic average for each group, observed a positive correlation between the academic average and self-perceived performance, as well as a positive correlation between students' disposition to mathematics and their self-perceived academic performance. McLeod & McLeod (2003) further provided a substantial review of literature discussing the difficulty of defining the term "belief", the variety of methods used for researching "belief", and implications for future research. They did, however, agree on the idea that "beliefs have strong relationships to both affective and cognitive processes that are important in mathematics education" (p. 115). Mason and Scrivan (2004) also ascertained that students' beliefs were significantly related to their mathematical and academic performance.

In a recent study, Schommer-Aikins, Duell, and Hutter (2005) investigated the role of beliefs on mathematical ability amongst 1,296 students from two middle schools in the Midwest. They showed that beliefs can have a heavy influence on the way students deal with problem-solving situations. They found that if the students assume that they should be able to complete all assignments in only a short amount of time, they tend to give up when they do not complete the assignment in their allocated time. Likewise, if the students believe that studying mathematics is aimless and therefore not useful, they may stop trying to be successful (ibid). As a result, Schommer-Aikins et al. (2005) suggested that challenging tasks in mathematics classrooms would be a good strategy for teachers to deal with some of the above issues.

It would appear that throughout the last decade, the role of affective factors in the learning of mathematics has received increasing attention from several different researchers (Ernest, 1994; Schuck & Grootenboer, 2004; Leder & Forgasz, 2006, Grootenboer & Hemmings, 2007). It also seems that the main rationale for most of these studies has been the shared assumption that there is a positive relation between students' mathematical beliefs, attitudes, and their mathematical achievement. However, as there are mixed results in the existing research which indicated that the relationship between students' belief and their ability in mathematical problem solving is not simple and systematic (Ruthven & Coe, 1994, p.101), it seems like a reasonable proposition that the relation between beliefs and performance requires further investigation. The present study was designed to investigate the relationship between grade 8th students' beliefs and their performance in mathematical problem solving.

Mathematical Beliefs Investigated in This Study

Beliefs are defined as the collection of cognitive concepts that developed gradually and with varying degrees of influence over ones' action (Abelson, 1979, Emenaker, 1993, Ensor, 1998; McLeod 1992, Thompson, 1992). The mathematical beliefs investigated in this study are those students' cognitive concepts that relate to the discipline of mathematics and to themselves as learners of mathematics, measured by the Indiana Mathematical Beliefs Scale, taken from Kloosterman and Stage (1992). They stated that this scale can measure two main groups of beliefs relevant to the motivation: *beliefs about the discipline of mathematics* through sub-scales 2 (word problems cannot be solved with step by step procedures) and 4 (word problems are important); and *beliefs about the individual as a learner of mathematics* through 1 (solving time-consuming problems), 3 (the importance of concepts in mathematics), 5 (the worth of paying effort in problem solving). As Kloosterman and Stage (1992) emphasized, these five beliefs are

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DOI: 10.15760/nwjte.2012.10.1.2

related to students' motivation for solving mathematical problems. They can also shed light on the incentive issues in students' problem solving in mathematics classrooms, particularly on the part of secondary school. Moreover, some of the above 5 subscales of beliefs (e.g. time, effort, set procedures) have been recognized in some other studies as common students' beliefs. Therefore, these beliefs are chosen for this study.

Method

In this study, a quantitative approach was taken to investigate the relationship between students' beliefs and their performance in problem solving. As such the researcher chose a group of 8th grade students studying at University Hill Secondary School in Vancouver. University Hill is a public secondary school in British Columbia, Canada.

Quantitative data about belief was gathered from a self-reported questionnaire. Students' performance in mathematical problem solving was measured through a problem solving activity.

Then, using SPSS software, the researcher conducted statistical analysis for both groups of data to answer her research questions.

Research questions

This paper aimed to answer to the following questions in detail:

1) What beliefs do secondary students have about mathematical problem solving?
2) Is there any relationship between students' belief and their performance in mathematical problem solving?

Participants

The current study recruited 27 eighth grade students (14 boys and 13 girls) from a public secondary school in Vancouver, BC. Students were from Canada (5 students), China (15 students), Iran (2 students), Korea (3 students), and Russia (2 students).

In order to undertake this study, the researcher met her niece's teacher who works in one of secondary schools of Vancouver. The availability of teacher's time was a significant factor in selecting this class for study. After explaining her purpose of the research, the teacher allowed the researcher access to the students. All students were provided with the opportunity to participate in the study and provided with parent permission forms. Those students who wished to participate in the study formed the sample.

Material

Two quantitative instruments were implemented in this study: a belief questionnaire and a problem solving activity.

The belief survey. The survey used self-reported data designed to measure eighth grade students' belief about problem solving. Students' belief was measured by the Indiana Mathematics Beliefs Scale, developed by Kloosterman and Stage (1992) to assess students' belief about problem solving. This instrument was selected as it was specifically designed for measuring students' belief about problem solving while others are meant to evaluate students' belief about mathematics in general. The Indiana Mathematics Beliefs Scale investigates students' opinion about five major beliefs regarding to problem solving in mathematics such as: (1) I can solve time-consuming mathematics problems; (2) there are word problems that cannot be solved with simple, step by step procedures, (3) understanding concepts is important in mathematics, 4) word problems are important, (5) effort can increase mathematical ability. The 30 questions match well with the above 5 scales and were distributed randomly by Kloosterman and Stage (1992) in order to put no item from the same scale in a single questionnaire

The performance test. The performance test, consisting of 5 mathematical problem solving questions, was used to measure how students perform in mathematical problem solving. The questions were selected from Trend in International Mathematics and Science Study, TIMSS (2003), for grade 8 students. TIMSS (2003) was selected because it was the most recent version of the test available online.

As the TIMSS (2003) is an international test developed based on a curriculum framework that includes content area which is representative of current school mathematics (e.g. algebra, data analysis, measurement, and number) and current performance expectations (e.g. knowing basic math facts, and solving problems) it was felt that this would provide a representative set of questions. As the main goal of this study was to investigate students' beliefs and its influence on their performance in mathematical problem solving, the performance test covered the expectations of students on solving the problem.

Procedure

The data were collected in March 2011; this was approximately eight months after students were introduced to a new curriculum in which the main emphasis is on teaching pupils through problem solving. Mr. B, the teacher, mentioned that his main teaching goal is making pupils more aware of implementing mathematics in real life by introducing them non-routine problems. Hence, I have thought this is a class can be a good research group. A week prior to beginning data collection, the researcher sent both the questionnaire and performance activity to the teacher who had agreed to let his class students to take part in this research. A few days prior to the delivery of the task, the teacher explained the aim of the research to students and emphasized that participation in the research is voluntary and requires parental consent. He further emphasized that the responses should be honest and all responses would be treated with the highest confidentiality and that no one other than the researcher would have access to individual responses.

The students' performance test and the questionnaire were given to the pupils in the following order: first, the performance test was administered with ten minutes provided for completion. This was immediately followed by the belief questionnaire with 30 minutes being allotted for completion.

Data analysis

To analyze the quantitative data, both the belief questionnaire and performance activity were scored. Quantitative measures were used to create data for two variables in this study: students' beliefs, students' score regarding their performance in mathematical problem solving. The "students' beliefs questionnaire" and "the performance activity" resulted in two quantitative scores for each participant: one score for students' beliefs and one for performance in problem solving.

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Students' Beliefs Scoring

The questionnaire used a Likert scale format. The five points on rating scale are Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD). In the beliefs questionnaire, the participants could choose one of those responses choices (e.g. SA, A or N). Some of the items on the scales were identified positive and others were negative.
Each of the items in the belief scale was scored by allocating a 1 to the least positive (strongly disagree) and a 5 to the most positive response (strongly agree). The total score for each participant from the 30 items was summed in order to give a total score of each student's belief, with 150 responding the most favorable belief (if the participant get 5 for each of the 30 questions) and 30 the least (if the participant get 1 for each of the 30 questions). As Kloosterman and Stage (1992) recognized, there is a potential for confusion over the term "word problem" in the belief questionnaire, so the researcher explained the term to the respondent in advance.

Students' performance scoring

To score the students' performance, TIMSS (2003) scoring criteria was followed; 1 point was given to the correct answer and 0 for a wrong one. The total raw score was 5 points, if the participant gave correct answers to all the questions. The raw scores were calculated as percentage correct.

After all data was collected, it was organized and analyzed in order to respond to the research questions. The analysis included descriptive and inferential statistics.

Results

The SPSS software was implemented to perform statistical tests and analyze the quantitative data. Each participant's response from the belief survey was used to determine the percentage of participants selecting one of the five possible choices for beliefs items. Then, the overall score of each student in problem solving performance was measured. Finally, in order to analyze the relationship between students' beliefs and their performance in problem solving, the Pearson correlation (r) was conducted.

Students' beliefs. First, the scores for the 30 items were summed to provide a belief score for each student participated in this present study. The maximum possible score of 150 shows the most positive belief and the minimum possible sore of 30 represents the most negative beliefs. The participant score variety from a low of 83 to a high of 117 with a mean of 102.60 and standard deviation of 8.9. Most of participants score (92.6%) was between 90 and 150 (the upper half of this possible range). In order to have a better description of students' tendency to subscales of beliefs, the researcher combined the percentage for Strongly Agree with Agree, and Strongly Disagree with Disagree in the belief questionnaire. Combining the percentage for Strongly Agree and Agree columns related to the question of whether "time-consuming is worthwhile" showed that 92.6% of participants agreed or strongly agreed that spending a longer time on mathematics problems is valuable. However, none of students believed that it is not worthwhile to spend their time on a question that needed a longer time to be solved and 7.4% of participants did not have any opinion.

The analysis of participants' responses to the question that "word problems cannot be solved with simple, step-by step procedures" revealed that 11.1% of participants agreed or strongly agreed that following a step-by-step procedure is not always necessary; 7.4% of them disagreed or strongly disagreed with this opinion. Surprisingly, 81.5% of participants did not express any idea about step-by step procedures.

The analysis of participants' responses to the questions about whether understanding concepts is important in mathematics revealed an interesting set of findings. A total of 85.5% of the participants believed that understanding plays an important role in solving math problems. What made it more interesting was that, only 3.7% of students disagreed or strongly disagreed with importance of understanding, and about 11.1% of respondents had no opinion about this item.

The participants' responses to the items related to the importance of word problems illustrated that 44.4% of students strongly agreed or agreed and 48.2%of them had no opinion. Also, the results showed that 7.4% of the participants disagreed or strongly disagreed with the importance of word problems in mathematics.

Finally, the analysis of students' responses was relevant to their tendency to do more effort in solving mathematical problem. These results revealed a very significant finding. It demonstrated that 96.3% of participants strongly agreed or agreed that effort can enhance their mathematical ability. Examining the percentage of disagreement for this item added the additional support for the belief that more effort can increase their ability in solving math problems. Meanwhile, the data indicated that only 3.7% of students had no idea about this category. The quantitative results showed that students' views about spending more time on time-consuming problems, the importance of understanding concepts and the value of doing more effort on solving the problems, was strongly positive amongst other items (92.6%, 85.2% and 96.3% students agreed or strongly agreed). This indicates that participants were in common agreement that spending time on time-consuming problems is worthwhile, effort can increase their mathematical ability and understanding concepts is important in mathematics. However, less than half of the participants (44.6%) expressed agreement that word problems are important in solving the problems, and less than those (11.1%) supported this belief that word problems cannot be solved with simple, step-by step procedures.

The relationship between Students' beliefs and performance. In order to investigate the relationship among students' mathematical beliefs and their performance in mathematical problem solving, the Pearson correlation procedure was performed on a total of seven variables: for six belief variables (total students belief and its 5 subscales) and students' performance.

The correlation coefficient (represented by "r" in this section) normally ranges from -1 to +1. The total students' belief was significantly and positively correlated with their performance in mathematical problem solving ($r = .887, p<.01$). This data means that the participants with higher performance in problem solving have stronger set of beliefs about mathematics. In fact, students' performance in mathematical problem solving was significantly correlated with three belief subscales: time consuming is worthwhile ($r =.485, p<01$); important to understand a concept ($r =.699, p<01$), and do more effort ($r = .644, p<01$). No significant correlation was found between students' performance and the other two belief subscales: *Problem solving is not always step-by step*, and *word problems are important*.

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DOI: 10.15760/nwjte.2012.10.1.2

Discussion and Conclusion

Within field of educational psychology and mathematics education, scholars have for some time assumed a positive relationship between students' beliefs and students' math performance (Muis, 2004). However, math beliefs traditionally have been explored separately from their performance in problem solving and few studies have investigated students' beliefs and students' performance through problem solving in the same studies (Schoenfeld (1985), Purvis (2000), and McLeod & McLeod (2003). Consequently, the traditional assumption of a positive relationship between students' beliefs and their performance in mathematics has not been substantially and empirically tested, particularly in the problem solving area (Kooler, 2001). The present study is among the few studies to include students' beliefs about problem solving and its influence on their performance in the same study. In this study, data was collected through two instruments: the Indiana Mathematics Beliefs questionnaire for measuring students' beliefs, and a problem solving activity, taken from TIMMS (2003), for measuring the participants' performance in problem solving. After analyzing data the following answers were found for two research questions in this study.

Q 1: What beliefs do secondary students have about mathematical problem solving?

The findings of the current study illustrated that the majority of the secondary students (participants of this study) believed that they should spend sufficient time and effort in order to learn mathematics. Also, in their point of view understanding mathematical concept play a vital role in learning mathematics. However, a small number of them thought that word problem are important and there are word problems that cannot be solved with simple, step by step procedures.

Q 2: Is there any relationship between students' belief and their performance in mathematical problem solving?

The results showed that students' math performance was positively and significantly related with their total score on the belief questionnaire ($r = 0.887$, $p < 0.01$). With closer examination, the researcher found that there is a positive and significant correlation between students' performance in problem solving and the following beliefs: 'Effort can increase mathematical ability (effort pays)'; 'Understanding concept is important in mathematics'; and 'I can solve time-consuming mathematics problems'. These beliefs are relevant to the ways students as individual learns mathematics. They believed that spending enough time, understanding concepts and expending enough effort supported them when learning mathematics. However, no significant relationship has been found between students' performance and their beliefs about *the importance of word problems* and *solving word problems through step-by-step procedure*, which are mainly relevant to mathematics as a discipline. It seems students who think the word problems are not more important than computational skills in mathematics may not perform very well in problem solving.

Joining a small, but developing body of research, this study at least partly clarified those beliefs supporting secondary school students' performance on solving mathematical problems. In fact, students who had stronger beliefs about spending more time and effort on solving the math problems, and those who believe in the importance of understanding the concepts would perform better than those who value the word problems and step-by- step procedures in mathematics. The results of this study support the findings that students' beliefs in memorization and step-by-step procedures can limit their mathematics performance (Masoon, 2003).

From the educational perspective, the following implications would be advisable for students. It might be worthwhile for students to be encouraged to spend more time on time-consuming problems. Step-by-step procedures in mathematics have important limitations, and time spent on understanding concepts is worthwhile. Word problems are an important part of mathematics, and more effort incorporating them in curriculum will pay off as students achieve more success in their mathematics. Teachers might also benefit from providing encouragement to students as they develop these beliefs mentioned in this study.

In terms of implication for the future research, much research is still needed to include other variables playing a role on beliefs in mathematics education, such as the relationship between beliefs and classroom contexts, the impact of different domains on students' beliefs, and whether (and how) beliefs may permanently change for the better.

Limitation of this study is implementing self-report scales. The self-report measures can be criticized due to relying solely on self-report and students' memory. In fact, students' memory for specific events may be inaccurate and their responses may be inconsistent. Due to the limitation of self-report scales, a more valid approach would be to include both qualitative and quantitative measures. For instance, a questionnaire followed by statistical analysis could be combined with interview or observation followed by in-depth qualitative analysis in order to understand how beliefs influence students' behaviors.

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