Importance and Centrality of Various Beliefs Held by High School Mathematics Teachers

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The central beliefs of mathematics teachers play a crucial role in shaping their teaching practices and determining how their students learn mathematics. This study presents the relative importance of various beliefs held by mathematics teachers. The study surveyed over 300 high school mathematics teachers in Pakistan (using a Likert scale of 1 to 5), exploring which beliefs are most important and how central beliefs impact their teaching. The results show that beliefs about exploring problems to discover patterns, textbooks, memorization and mathematical signs, notations, and symbols have many connections and correlations with other beliefs. These beliefs may potentially serve as the central beliefs in the teachers' belief system.

Introduction

The central beliefs of mathematics teachers play a crucial role in shaping their teaching practices and determining how their students learn mathematics. Positive beliefs about mathematics teaching and learning create an environment of support and exploration (Maasepp & Bobis, 2014). They encourage students to understand mathematics concepts and theories rather than merely memorizing facts and equations (Säljö, 2010). Several studies indicate various beliefs that mathematics teachers hold (Amirali & Halai, 2021; Beswick, 2007; Lloyd, 2002; Pajares, 1992; Schoenfeld, 2011; Yurekli et al., 2020). However, not all beliefs are equally important because "beliefs vary along the central-peripheral dimension" (Rokeach, 1968, p. 3). Only the central beliefs, as they have more connections with other beliefs in our belief system, are important (Rokeach, 1968). Based on any given knowledge, if an individual holds a particular belief, then it is likely that they may hold certain further related ideas and attitudes (Barton & Parsons, 1977). That is, there is a relationship between beliefs, and certain (central) beliefs may cause changes in other beliefs and behaviour (Muijs & Reynolds, 2015). Thus, to understand teachers' beliefs, one has to understand their central beliefs. Examining the information about central beliefs could provide an understanding of how teachers perceive and approach mathematics teaching and learning and may locate areas for professional development or ways to support teachers in enhancing their teaching practices.

Purpose of the Study

The purpose of the paper is to present quantitative findings that determined the relative importance or centrality of various beliefs held by mathematics teachers in Pakistan. In particular, the study aimed to explore what beliefs are most important to teachers and how central beliefs influence other beliefs about teaching and learning mathematics. The study focused on investigating the beliefs held by teachers concerning the nature of mathematics, their teaching practices, and the use of resources in teaching and learning mathematics.

Theoretical Framework

There has been a plethora of literature on understanding teachers' beliefs in educational psychology (Ernest, 1989; Pajares, 1992; Schoenfeld, 2011). The previous studies provide understanding why teachers do what they do and how they behave in response to different pedagogical situations. Philipp (2007, p 259) define beliefs as "psychologically held understandings, premises or propositions about the world that are thought to be true." Considering beliefs as a psychological construct, Philipp (2007) emphasized on a continuous need to investigate and understand teacher system of beliefs. In relation to mathematics, Jafri (2022) articulates mathematics

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teachers' beliefs as opinions, dispositions, (pre)-conceptions, and philosophies they hold about the nature of mathematics and its teaching as a whole. Jafri argues that a teacher could develop a "self-confirming bias" about a particular teaching practice or a resource because that is how he or she learned when they were a student. Such biases could lead a teacher to believe that the way he or she learned is the only effective way to teach. Based on their personal life experiences, socio-cultural and religious contexts, mathematics teachers may hold identical or different beliefs (Amirali & Halai, 2021). Notably, religious contexts and beliefs, no matter how strong or subtle they may be, impact teachers' beliefs about mathematics, and teachers apply them to their (mathematics) teaching (Chan & Wong, 2014). However, as religious beliefs are rich in content, teachers may apply only a portion of them to their teaching. As beliefs become more widely accepted and practised, they become part of the social context of teaching (Ernest, 1989). Subsequently, these beliefs become a widely shared belief system among the majority of the teachers, serving as the foundation for their thought process, behaviour, and interactions with each other and their students (Pajares, 1992). However, not all beliefs may be equally important for teaching and learning mathematics. "Beliefs vary along the central-peripheral dimension" (Rokeach, 1968, p. 3). Only the central beliefs are important because they have more connections with other beliefs in our belief system (Rokeach, 1968). These central beliefs are most difficult to change (Ertmer & Ottenbreit-Leftwich, 2010). Therefore, they need to be addressed and examined as they drive classroom actions and influence the teacher change process. (Richardson, 1996).

The beliefs become central if we learn them during childhood and involve a direct encounter with the object of belief (Rokeach, 1968). For example, a belief that mathematics textbooks are important for teaching does not only involve an object; it is further reinforced by the unanimous social consensus among all of one's reference persons and groups (Jamieson-Proctor & Carmen, 2008). However, if we consider beliefs to be a collection of attitudes, then beliefs that play a critical role within a person's belief system and help in determining his or her behaviour are important (Rokeach, 1968). We hold such beliefs within the innermost core of the belief system, and they act as central beliefs (Rokeach, 1968). Such biases and beliefs may inhibit a teacher's desire to change teaching practices related to the belief (Pajares, 1992) and are normally unaffected by new information (Ernest, 1989). Therefore, it is essential to determine the relative importance or centrality of various beliefs held by mathematics teachers.

Rokeach (1968) defines importance in terms of connectedness. They suggest that the more a given belief communicates or has functional connections with other beliefs, the more we can consider it a central belief (p. 5). Nonetheless, central beliefs are a small set of beliefs that has more implications and consequences for other beliefs in the belief system. Rokeach proposes criteria for functional connectedness or functional communication. They argue that beliefs that are directly concerned with our existence and identity and that we share with others are important. These beliefs have more functional connections and consequences than others. Whereas beliefs that are derived and are concerned with more or less arbitrary matters have fewer functional connections and consequences for other beliefs. Although, Rokeach's theory of central beliefs has been influential in psychology and sociology, it criticised due to its oversimplification. Rokeach's theory suggests that individuals have a relatively small set of central beliefs that guide their behaviour. However, some researchers (Festinger, 1962; Pajares, 1992) argue that beliefs are complex and multifaceted and that individuals may hold conflicting or contradictory beliefs. Under a particular social context of teaching and the teacher's level of thought processes and reflection, beliefs could change (Ernest, 1989). Influenced by the social context, teachers are likely to adopt the same teaching methods despite holding differing beliefs about mathematics (Pajares, 1992). For example, when teachers employ curriculum materials in their classrooms, they could potentially develop new mathematical and pedagogical beliefs and skills based on their design of lessons, conversations with students, use of technology, and so on (Lloyd, 2002). However, Yurekli et al. (2020) argue that several constraints

(or factors) existing in the educational environment, such as assessment methods and students' understanding of mathematics, cause discrepancies between beliefs and practices.

In terms of measurement of central beliefs, Barton and Parsons (1977) assume that the degree to which an attitude is important or central to the individual is one of the most critical attributes requiring measurement. Barton and Parsons relate strength of belief to the degree to which an individual holds the attitude and the willingness to act on it. We can measure it by how much effort an individual is willing to expend to maintain an attitude or defend the belief. One can assess this through self-report surveys, attitude scales and experiments. For example, a survey might ask respondents to rate the importance of a certain belief on a scale of 1 to 5, with 5 being the highest score (Bautista et al., 2020). Other methods for measuring attitude strength include observing how quickly an individual responds to questions related to the attitude, how frequently the individual mentions it in conversation and how strongly the individual expresses agreement or disagreement with the attitude.

Methodology

This paper presents quantitative results from an ongoing doctoral investigation that uses a mixed-methods approach. The main study utilized an online survey to acquire quantitative data. High school mathematics teachers from Pakistan volunteered to complete an online survey. The aim was to recruit teachers with varied number of years of teaching experience from both government and private schools in Pakistan's rural and urban areas. However, this study only presents the data and findings framed around the research question:

- What are the central beliefs of mathematics teachers and how are they connected with other beliefs?

We presented the seven (07) beliefs about the nature of mathematics teaching and learning as statements in the online survey, which are as follows: (1) Learning mathematics means exploring problems to discover patterns and make generalisations (B2_1); (2) Mathematics teaching is to teach students how to create and assign meanings to signs, symbols, and notations (B2_2); (3) Mathematics teaching is to share knowledge and ideas, and to discuss a variety of real-world contexts (B2_3); (4) Mathematics lessons should be followed by a critical discussion with students (B2_4); (5) Mathematics curriculum textbooks are the best medium of instruction and source of knowledge (B2_5); (6) Mathematical knowledge is retained more easily if it is acquired using multiple representations (B2_6); (7) While learning mathematics, it is important to memorize rules, facts and formulae (B2_7).

Based on Bautista et al. (2020), the high school mathematics teachers were asked to submit their agreement or disagreement on a Likert scale of $1\ to\ 5$ (1 strongly disagree and 5 strongly agree). More than 300 high school mathematics teachers in Pakistan responded to the survey. After initial screening and removing incomplete responses, the study selected 270 responses for analysis.

The study used descriptive statistics to measure the central position within the data and Spearman's Rho (ρ) correlation test to understand how mathematics teachers' beliefs were correlated. Barton and Parsons (1977) consider correlation coefficients as a general method of measuring the structuredness of attitudes and beliefs. The test measured the strength and direction of association that may exist between teachers' beliefs. The two assumptions for Spearman's Rho were satisfied. First, we measured the scores using an ordinal scale—a measurement scale that uses labels to classify cases into ordered classes, such as the Likert scale (strongly agree to strongly disagree). Second, the relationships between items were monotonic, i.e., if the value of one item increases, so does the value of the other item.

Findings

The study calculated descriptive statistics and correlations between the beliefs. Table 1 shows the results of descriptive statistics. The first column shows the code associated with each belief statement. The second column contained belief statement. The remaining columns shows the measure of central tendency i.e., Mean, Median, Mode and Standard deviation (SD).

Table 1

Descriptive Statistics

Item No.	Item Statement	Mean	Median	Mode	SD
B2_1	Learning mathematics means exploring problems to discover patterns and make generalisations.	4.71	5.00	5	0.46
B2_2	Mathematics teaching is to teach students how to create and assign meanings to signs, symbols, and notations.	4.24	4.00	5	0.62
B2_3	Mathematics teaching is to share knowledge and ideas, and to discuss a variety of real-world contexts.	4.51	5.00	5	0.51
B2_4	Mathematics lessons should be followed by a critical discussion with students.	4.50	5.00	5	0.61
B2_5	Mathematics curriculum textbooks are the best medium of instruction and source of knowledge.	4.07	4.00	4	0.64
B2_6	Mathematical knowledge is retained more easily if it is acquired using multiple representations.	4.59	5.00	5	0.63
B2_7	While learning mathematics, it is important to memorize rules, facts, and formulae.	4.73	5.00	5	0.55

The descriptive results showed that apart from beliefs about signs, symbols, and notation (B2_2), and the importance of textbooks (B2_5), the rest of the mean values were 4.5 and above, which suggests teachers hold firm beliefs about mathematics teaching and learning. Teachers held robust beliefs about pedagogical practices, such as exploring problems to discover patterns and making generalizations, conveying mathematical knowledge through multiple representations, critical debate with students and sharing mathematical ideas. The study found the highest mean value (4.73) was for belief about memorizing rules, facts and formulae, indicating memorization as the most familiar pedagogical practice among teachers.

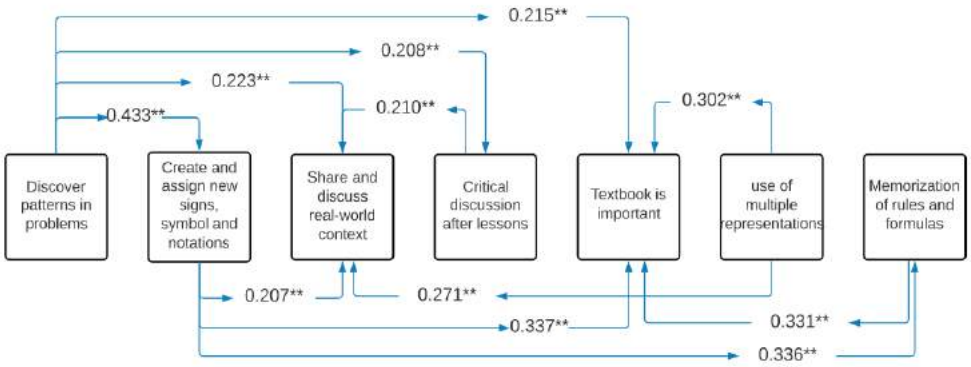

Figure 1. Correlation coefficient $\rho > 0.2$ ($p < 0.01$).

The results of the Spearman's correlation test are shown in Figure 1, showing correlation coefficient (ρ) marked with ($**$) representing the statistical significance (2-tailed) p-values at 0.01 for seven beliefs. To establish the importance of beliefs, the study only considered correlations coefficients with values greater than or equal to 0.2 ($\rho > 0.2, p < 0.01$).

The study found significant p-values for the Spearman Rho test. These values provide strong evidence that most beliefs are monotonically correlated. For example, the highest correlation ($\rho = 0.433, p < 0.01$) was found between learning mathematics through exploring patterns in mathematical problems and to generate new signs, symbols, and notations. Notably, the two beliefs 'learning mathematics means exploring problems to discover patterns and make generalizations' and 'how to create and assign meanings to new signs, symbols, and notations' reported significant correlations with all other beliefs. In particular, the correlation was relatively strong with teachers' beliefs about textbooks and memorization. Mathematics textbooks also revealed significant correlations with other beliefs about teaching and learning mathematics.

The findings showed that the teachers' beliefs about 'signs, symbols and notations', 'memorizing rules and formulae', 'textbooks' and 'exploring problems to discover patterns and make generalizations' revealed significant correlations with other beliefs about teaching and learning mathematics. The use of a textbook correlated positively with 'memorizing', 'multiple representations', 'critical discussion with students' and 'teaching real-world contexts', 'signs, symbols and notations', and 'exploring problems to discover patterns.' The correlations were relatively high with the 'memorization of rules and formulae; 'the use of multiple representations'; and 'signs, symbols, and notations.' The study also found that the belief about sharing 'knowledge and teaching mathematics using real-world contexts' was relatively weakly correlated with other beliefs about mathematics teaching and learning.

Discussion

The study explored the central beliefs of mathematics teachers and how they influence other beliefs in the teacher's belief system. Due to constraints of space, we here primarily discuss the main findings of the study. The findings about memorizing are consistent with the body of literature on the beliefs of mathematics teachers. For example, the belief about memorizing facts and formulae received the highest mean score of 4.73. It is typical for teachers to believe that students should memorize, repeat, and imitate exact sequences of calculations and operations (Säljö, 2010). This notion is generally based on the idea that mathematics is a set of fixed rules, with little room for creativity or interpretation. With such an approach, teachers tend to focus on the correctness of students' answers, rather than the process of how they arrived at those answers (Schoenfeld, 2011). This suggests that beliefs about memorization may have more connections with other beliefs.

The findings suggest memorizing rules and formulae was relatively high in correlation with students' ability to create and assign meaning to new signs, symbols, and notations ($\rho = .336, p < 0.01$) and the teacher's use of mathematics textbooks ($\rho = 0.331, p < 0.01$). Considering that high school mathematics textbooks involve a wide variety of signs, symbols, and notations along with rules and formulae, their relationship with memorization may be significant. It suggests that the more teachers consider textbooks as an important source of information in the classroom, the more rules and formulae students are required to memorize. This is an intriguing finding in the context of problem-solving, implying that teachers believed students who memorize rules and formulas could create their own signs and symbols to assist them in solving mathematics problems. In education psychology, creative or innovative act of producing or interpreting signs or symbols is called an "inventive-semiotic act" (Goldin, 1998), an important teaching belief, which helps students understand mathematics better. Goldin (1998) argues that once students create and assign meaning to problems, they then move on to explore the logico-mathematical consequences of their inventions-in effect, learning to build their own (external and internal) mathematical representations. A teacher with such beliefs can help students learn the signs and symbols used in mathematics. Whereas Memorization is the process of committing information to memory through repetition or other techniques (Säljö, 2010). The only possible relationship between the two concepts is, both involve cognitive processes related to language and meaning. Memorization may be necessary to engage in inventive-semiotic acts, as the ability to recall and manipulate language and symbols is essential for creative expression. However, memorization alone does not guarantee the ability to engage in inventive-semiotic acts, as creativity involves the generation of new ideas and connections that go beyond rote memorization. We recommend further research into the two beliefs may help establish any possible connections.

An important factor that may play a role in teachers' adherence to memorization-based teaching strategies is their socio-religious affiliation. Amirali and Halai (2021) found that socio-religious experiences shape high school mathematics teachers' beliefs about mathematics in Pakistan. Most parents prefer their children to memorize the sacred book Qur'an even before starting school. A child (called "Hafiz") is expected to memorize exact written and exact vocal reproduction of verses. Typically, memorization is perceived as a tedious and repetitive form of learning. However, in Islam, scripture memorization is seen as a benefit from a moral, spiritual, and intellectual perspective (Kabir, 2021). Such a social, religious, and emotional influence may explain the teachers' deep connection with the practice of memorization as a core method of teaching in mathematics classrooms (Chan & Wong, 2014). It could further justify the weak relationship of "critical discussion after lessons" in the survey data with other teachers' beliefs. However, in students memorizing and imitating teachers' explanations of mathematics problems, the content learnt is limited to the textbook and its particular selection of information (Säljö, 2010).

Regarding the textbooks, only 39% of survey teachers strongly agreed, whilst 40% somewhat agreed that mathematics textbooks are the best source of information. A slightly surprising result considering previous literature on the use of textbooks. Historically, mathematics teachers have always placed a high value on and are closely linked to the textbooks to which they have access (Jamieson-Proctor & Carmen, 2008). It appears to be signalling a shift away from textbook-centered teaching to other contemporary educational resources, such as the use of digital resources. However, whether teachers make less use of the textbooks, might be or might not be the case considering that the data was collected during the lockdown when teachers were mostly using digital technologies (Jafri, 2022). The COVID-19 online teaching and learning may have influenced the results. Textbooks are widely available and have always played an important role in directing teaching approaches in Pakistan (Amirali & Halai, 2021). This could be the cause for the notable correlations between beliefs about the usage of textbooks and teachers' other beliefs about mathematics. The correlations were relatively high with the memorization of rules and formulas, the use of multiple

representations, and the creation of new signs, symbols, and notations in mathematics teaching and learning.

Further, the belief about sharing knowledge and teaching mathematics using "real-world contexts" correlated with other beliefs about mathematics teaching and learning. However, its correlation with memorization was weakest ($\rho = 0.158, p < 0.01$). Teachers who are more likely to use real-world contexts in their teaching also tend to believe that mathematics is a creative subject (Karakoç & Alacacı, 2015). Such teachers emphasize problem-solving over memorization, and they encourage students to explain their mathematical understanding. Notably, over 63% of teachers think post-lesson critical discussion and the use of multiple representations in classrooms are important. This shows discrepancies, i.e., teachers' beliefs about post-lesson critical discussion may have fewer connections because of inconsistent beliefs. For instance, critical discussion requires teachers and learners to articulate their ideas, whereas memorization as previously discussed involves committing information to memory. It is unclear how students can critically discuss a lesson that they have just memorized or imitated, or how memorization and multiple representations can coexist. Inconsistencies in beliefs articulate teachers' desire to create an ideal or alternative teaching and learning environment (Pajares, 1992). Teachers may have flexible beliefs, which allows them to layer existing beliefs by accepting diverse sets of information and taking influences from different resources they use to teach mathematics (Schoenfeld, 2011). We can argue that changes in context and situations, such as COVID-19, may have induced changes in their practices and that their beliefs are changing (Jafri, 2022). However, the survey data cannot determine the extent to which these beliefs influence changes in teachers' pedagogical practices.

Overall, the above discussion shows that 'exploring problems to discover patterns and make generalizations' (B2_1) and the 'use of signs, symbols and notations' (B2_3) have more connections and most likely communicate with other beliefs about mathematics teaching and learning. These beliefs are relatively high in correlation with the beliefs about textbooks, which is relatively high in correlation with memorizing rules and formulae. These beliefs may potentially serve as the central beliefs in the teachers' belief system. They instil a sense of purpose and motivation in teachers as they strive to provide and teach mathematics in real-world contexts using an object of belief (textbook). Teaching students how to create and assign meanings to new signs, symbols, and notations may involve using logic, reasoning, and problem-solving skills to solve equations, understand concepts, and explore relationships (Goldin, 1998). Though memorization revealed fewer, albeit relatively higher correlations with other beliefs, it may have strong socio-religious belonging and acceptance. Rokeach (1968) argues beliefs based on faith or religion are more central than others. This socio-religious context could bring memorization as one of the central beliefs for mathematics teachers in Pakistan. The findings discussed in this article highlight the evidence-based relationship of teachers' central beliefs and their connections with other beliefs. As the field of mathematics education continues to evolve, it will be important to continue exploring and understanding the beliefs and how they influence practices of mathematics teachers.

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