Investigating Pre-service Elementary Teachers' Mathematical Power

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Abstract
Mathematical power affects in developing pre-service teachers' ability to use the information to think creatively, solve problems, and reflects critically on challenges. However, concerns regarding the low mathematical power held by pre-service teachers have raised serious inquiries about the efficiency of teacher education programs. This study aimed to investigate pre-service elementary teachers' mathematical power using a mixed-method research design. The participants included 71 pre-service elementary teachers at a university in Saudi Arabia. Quantitative data were collected using a mathematical power test, and interviews were used to collect qualitative data. The findings showed that pre-service teachers had a low level of mathematical power, and there were three factors that contributed to the pre-service elementary teachers' low level of mathematical power.

***Keywords*:** elementary education, pre-service teachers, mathematical power, mathematics

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Article Received: 18 October 2020, Revised: 3 November 2020, Accepted: 24 December 2020

Introduction

Mathematics is the science that deals with the arrangement, quantity, and relationships that involves measurement, arithmetic and the illustration of objects (Sukasno, 2016). Mathematics has a big influence on the development of science and technology. It plays a critical role in processing the reasoning power of students. Cockcroft (1986) argues that it is very difficult to live a natural life without using mathematics. It significantly supports the student's development. Teachers should constantly support the importance of mathematics in real life.

Interest in learning mathematics appears from the teachers' commitment to create a classroom environment that simulates students' interest in learning, develops students' procedural literacy, advances key capabilities through problem-solving analysis, builds on students' abilities to think hypothetically, reasons in concrete and abstract terms, and comprehends cause and effect (Protheroe, 2007; Shellard & Moyer, 2002). In brief, teachers should foster their skills in mathematics teaching to improve student interest and achievement in mathematics (Sukasno, 2016).

Mathematics teaching reform is concentrated on the improvement of mathematical power of each student (National Council of Teachers of Mathematics [NCTM], 1989). Mathematical power is students' or teachers' possession of mathematical abilities, including mathematical concepts, procedures, and processes, such as mathematical reasoning, mathematical correlation, and mathematical communication (Helioh, 2015). Kusmaryono (2014) argued that teachers play a major role in the development of students' mathematical power by understanding how students learn; creating learning activities that encourage students' motivation; and having a dynamic personality in the planning, implementation, and assessment of learning. However, concerns regarding the low mathematical power held by pre-service teachers have raised serious questions about the effectiveness of teacher preparation programs.

Teacher education programs aim to assure that their student teachers demonstrate efficient teaching (Al Sultan, 2020). Teacher education programs are conceived as regulated educational practices that are anticipated at the purposeful coordinated preparation of teachers (Naik, 2013). They are conceptualized as the most critical stage in teachers' lives through which they can acquire knowledge, skills, and readiness for teaching (Safari

& Rashidi, 2015). Teacher education programs prepare student teachers to teach all subjects in their classrooms. Only a well-prepared teacher can provide proper guidance and instruction. Therefore, the quality of education at schools depends mainly on teacher education programs. Several lines of research evidenced that public education will be enhanced only through well-qualified and smart graduates. For example, Ravitch (2007) argued "Our graduates are number one. If you are not lucky enough to get our graduates, you might have to hire people from alternate routes" (p. 273). Teacher education programs are challenged to prepare their student teachers to realize high levels of mathematical power. As Safari and Rashidi (2015) put it, despite reforms in approaches to teacher education programs from the transmission to post transmission pedagogy, the focus of teacher education remains the traditional issues of classroom management and instruction. Effective practices of teacher education programs should focus on teachers' development and subsequently on their students' learning process. Given the problems that teachers face in teaching mathematics for the future success of their students, teacher education programs must be guided by a well-articulated vision to prepare teachers to meet those challenges through providing them with the needed knowledge, skills, and process to promote the mathematical power of their students.

Previous research has established that low levels of mathematical power can lead mathematical teachers to teach it poorly. For that, this study poses the following two questions:

1. What are pre-service elementary teachers' mathematical power levels in teaching?
2. Why do pre-service elementary teachers have high or low mathematical power levels in teaching?

Theoretical Framework and Review of Literature

Mathematical power

The concept of mathematical power is one of the new concepts in mathematics as it is considered a standard in evaluating students' learning in mathematics. Mathematical power is an atypical method used by educators to measure learners' progress in mathematics (Zankor, 2008). It is the beliefs in one's capabilities to use mathematical knowledge (perceptual comprehension, and procedural knowledge) to solve illogical problems, make logical reasoning, and communicate about mathematics, and the interdependence of mathematical ideas (El-Said, 2005).

Mathematical power is conceptualized as the capability of the person for utilizing his/her theoretical and functional knowledge within the framework of decisive content in solving the problematic situation using his/her communication, reasoning and connection skills (MandacÕ ùahin, 2007). It involves learning procedures through reasoning, understanding, problem-solving, connecting mathematical concepts, and communicating mathematics to others (National Research Council [NRC], 1989).

Mathematical power means the person's abilities necessary to investigate, conjecture, and reason logically, as well as the capability to utilize different mathematical methods efficiently to solve anomalous problems (NCTM, 1989).

By mathematical power, we mean the ability to (1) assess, and reason logically, (2) communicate about and through mathematics, (3) connect the ideas in the mathematical concepts and between mathematics and other sciences, (4) solve the problems that are not conventional, (5) develop self-confidence, and use information in solving problems and making decisions (Kusmaryono, 2014). More specifically, mathematical power is shaped by some major forces: (1) engagement in mathematical problem solving, (2) mathematical reasoning, (3) connecting what is learned in mathematics with other disciplines, (4) mathematical communication, (5) confidence in one's own mathematical capability, and (6) appreciating the significance and importance of mathematics (NCTM, 1989). Mathematical power is also known as all that enable students to employ the four mathematical operations (Communication, correlation, mathematical reasoning, and mathematical representations) at the level of conceptual knowledge, procedural, and problem solving (Mohammad, 2011).

Mathematical power is very significant for pre-service mathematics teachers because it will affect (1) the way they learn to acquire knowledge, attitudes, and skills, (2) the students' success in interdisciplinary studies, (3) students' self-confidence, critical thinking, reasoning, use quantitative information and specials in solving problems and making decisions (Kusmaryono, 2014). Additionally, it affects in developing pre-service teachers' capability to use information to reason and think creatively and to solve, and reflect critically on problems and challenges (NCTM, 2000).

Given the critical importance of the mathematical power in determining the level of teaching practices, mathematical power has attracted a considerable amount research in teaching mathematics (Kusmaryono, 2014; Mohammad, 2011; El-Said, 2005; Zankor, 2008). Several lines of empirical research have suggested that teachers with high levels of mathematical power are committed to teaching mathematics, are more likely to develop students' mathematical power through innovative methods of teaching, and to achieve meaningful learning experiences. As such, the purpose of the current research was to investigate pre-service teachers' mathematical power.

Mathematical Power Dimensions

Mathematical power is not limited to mathematical knowledge only, but takes into account all the processes that can be developed through learning mathematics. Mathematical power includes three basic processes: communication, correlation, and mathematical reasoning (Rayani, 2012; El-Said, 2005). Mathematical communication is conceived as the individual's ability to use and employ mathematical symbols and vocabulary to express ideas and understand the relationship between them (NCTM, 1989). In other words, it is the student's ability to produce representative examples of concepts and the use of shapes and drawings to articulate concepts in addition to use mathematical, manual, technological, intellectual manipulations, modeling concepts, and translating them into connotations (Rezq, 2012). Mathematical connection refers to the process by which learners perceive the connections between the different branches of mathematics, other disciplines of science, and build a perception of the usefulness of mathematics through its laws and logical methods (Rayani, 2012). It is highlight the relationship between the elements of mathematical content within the same domain, and the relationship between the different domains in a way that illustrates the coordinated and interrelated structure of mathematics, as well as show mathematical applications in other sciences and in life matters (Abu Al-Ajin, 2011).

The third dimension of mathematical power, mathematical reasoning, refers to a mental activity through which the individual moves from the whole to the parts, using proven information to reach solutions to problems (Hamshi, 2010). It is a thinking style related to problem solving, and helps to discover and produce information. More specifically, mathematical reasoning is a logical mental process in which the individual proceeds from known facts, to the knowledge of the unknown.

Methods

Research Design

This study used a mixed-method design, specifically the triangulation design. This design helps researchers to clearly understand the results of quantitative data using qualitative data (Creswell, 2014). In this study, a MPT was used to collect the data of the quantitative part that measured pre-service elementary teachers' mathematical power. The semi-structured interviews were used to collect qualitative data that measured the reasons of pre-service elementary teachers' responses.

Participants

Overall, 71 pre-service elementary teachers (36 men and 35 women) enrolled in a teacher preparation program at a public university in the eastern province of Saudi Arabia participated in this study. The program prepared the participants to teach students in grades one through three. The sample was selected through random sampling of the last course of the Primary Classroom Teacher Program and before participants teaching course.

Data Sources and Procedures

In the current study, researchers used both quantitative and qualitative techniques to collect data from the sample. The researchers used a MPT that was developed by Al wihaibi (2009). The MPT was developed to measure the mathematical power of high school students in Sultanate of Oman (Al wihaibi, 2009). The test comprised of fifteen questions that measured three domains (mathematical communication, mathematical connection, and mathematical reasoning).

Researchers developed the guide of interview to take the benefit of the available time with participants. According to Patton (2015), the advantage of interview guide is to help researchers benefit and manage the limited time available with the participants. Two mathematics education researchers reviewed the guide of interview. The guide of interview contained four questions that addressed the current research. Before conducting the interviews, the researchers used the interview guide with three participants who were not included with interview sample in this study to obtain feedback and estimate the interview time. Overall, participants needed 15 minutes to complete the interview.

Ethical approval was gained from standing committee for research ethics on living creatures in the university. All 71 participants in this study first responded to the test, where they received the instructions on how to complete the test and were informed about the goal of the study. On the same day, the participants were interviewed after they signed consent forms on participating in the study.

Procedure

Google's online survey service was used to create the electronic version of the MPT. To avoid any missing answers, the test questions were made to require all responses. All of the participants volunteered to contribute to this study.

Data Analysis Strategy for Quantitative Part

The current study used descriptive statistics to investigate pre-service elementary teachers' mathematical power first. Second, an independent sample t-test procedure was used to compare the mean scores across gender groups using the SPSS program.

Results

The goal of this research was to measure pre-service elementary teachers' mathematical power. This part includes three sections of information about the samples' demographic characteristics, their mathematical power (*mathematical communication*, *mathematical connection*, and *mathematical reasoning*), and their mathematical power based on their gender.

Demographic Characteristics

In Table 1, the participants' demographic characteristics according to their gender are provided. Fifty one percent of participants were male while 49 percent were female, and all participants were Saudi nationality.

Table 1:
Characteristics of Participants

		Frequency	%
Nationality	Saudi	71	100
Gender	Male	36	51
	Female	35	49

Pre-service Elementary Teachers' Mathematical Power

The test was analyzed to measure the pre-service elementary teachers' mathematical power (*mathematical communication*, *mathematical connection*, and *mathematical reasoning*). The mean scores for the three domains of MPT are reported in Table 2. The minimum possible score for each domain is zero, and the maximum possible score is ten. A higher score illustrates a high-level of mathematical power while a lower score illustrates a low level of mathematical power. *Mathematical communication* (M = 2.0563) was the highest score, followed by the *mathematical connection* (M = 1.8028), and finally, *mathematical reasoning* (M = 0.7606), which was the lowest score.

From Table 2, In general, the performance level of pre-service elementary teachers in the MPT was below the normal level of students in the population study, where the mean score of pre-service elementary teachers in the MPT was (M = 4.6197) which is less than the general mean score of the test (M = 15).

Table 2:
The Descriptive Statistics of Mathematical Power Test (MPT)

Test	Test Score	N	Min	Max	Mean	Std. Deviation
Mathematical communication	10	71	0	8	2.0563	2.34147
Mathematical connection	10	71	0	10	1.8028	2.57804
Mathematical reasoning	10	71	0	6	0.7606	1.66874
Mathematical power	30	71	0	22	4.6197	4.82365

Mathematical power Based on Gender

The mean scores, standard deviation, and t-test for the three domains of MPT (*mathematical communication*, *mathematical connection*, and *mathematical reasoning*) are reported in Table 3. The minimum possible score for each domain is zero, and the maximum possible score is ten. A higher score illustrates a more high level mathematical power while a lower score illustrates a more low level mathematical power. *Mathematical communication* for females (M = 2.1714, SD = 2.44331) and for males (M = 1.9444, SD = 2.26709) was the highest score, followed by *mathematical connection* for females (M = 2.0571, SD = 3.23531) and (M = 1.5556, SD = 1.73113) for males; and *mathematical reasoning* for females (M = 1.0857, SD = 2.13337) and (M = 0.4444, SD = 0.96937) for males, which was the lowest score. In general, the mathematical power for females was (M = 5.3143, SD = 5.79945), and for males was (M = 3.94444, SD = 3.59320).

An independent sample t-test indicated that there was no a statistically significant difference between male and female pre-service elementary teachers' mathematical power (t = -1.200, p = 0.234): *mathematical communication* (t = -0.406, p = 0.686), *mathematical connection* (t = -0.818, p = 0.416), and *mathematical reasoning* (t = -1.638, p = 0.106). Therefore, there was no a significant difference between male and female pre-service elementary teachers' mathematical power.

Table 3:
Results of Two-Tailed t-test of Pre-service Elementary Teachers' Mathematical Power

Test	Mean		Std. Deviation		t	df	p
	Male	Female	Male	Female			
Mathematical Communication	1.9444	2.1714	2.26709	2.44331	-0.406	69	0.686
Mathematical Connection	1.5556	2.0571	1.73113	3.23531	-0.818	69	0.416
Mathematical Reasoning	0.4444	1.0857	0.96937	2.13337	-1.638	69	0.106
Mathematical power	3.94444	5.3143	3.59320	5.79945	-1.200	69	0.234

Note. The p value: significant at the $p<0.05$ level.

Pre-service Elementary Teachers' Interviews

The purpose of the interviews was to reveal the reasons contributing to the pre-service elementary teachers' mathematical power. The analysis of the qualitative data highlighted three major reasons that affect their mathematical power. The first theme emerged from the interviewees' responses was the teacher educators. All the participants reported that teacher educators are supposed to contribute to their mathematical power development. Nonetheless, mathematical educators' traditional methods of teaching do not offer adequate opportunities for students to communicate mathematically. For example, one of the participants said, "our educators use traditional teaching methods that provide no opportunities to express our ideas." Another participant said, "teachers dominate the lecture giving few opportunities to communicate our mathematical ideas and concepts with them or with each other." Another participant was more explicit when he said, "throughout the semester, we had very few opportunities to discuss and connect mathematical ideas with one another." Other participants emphasized that educators do not encourage them to organize their thoughts on how to deal with mathematical situations. For example, one of the participants said, "our teachers provide insights into the mathematical situations and offer solution ideas. I have never asked to provide my own insights on how to deal with mathematical situations."

The second theme that affects the level of mathematical power was the pre-service teachers' beliefs and the low interest towards math. Having negative beliefs about the nature of mathematics is a stressor that significantly affects pre-service teachers' mathematical power. Most of the participants believed that Math is a hard subject. For example, one of the participants said, "mathematics is very hard to digest." Another participant said, "mathematics is a complicated difficult science." Researchers have emphasized that pre-service teachers' beliefs toward mathematics critically affect their mathematical power. Our participants reported that mathematics is not an easy science to learn. One of the participants said, “mathematics is a stiff, abstract subject, that’s very difficult to learn and understand its concepts.” Overall, the analysis of the interview revealed that the negative beliefs of the pre-service teachers around mathematics negatively contribute to their mathematical power.

The third theme emerged from the interviewees’ responses was the content knowledge. The participants in this study believed that the content knowledge in the elementary teacher preparation is very general that usually impede the students’ ability to link concepts when they encounter mathematical problems and provide appropriate solutions to them. One of the participants said, “the content of courses is very general. They do not improve the learning opportunities for us.” Another participant said, “I do not know a lot about many mathematical concepts and formulas, the content is very abstract and general.” The big challenge of the pre-service teacher program faces is the need to provide more relevant content knowledge in mathematics. For example, one of the participants said, “I really need to learn more about mathematics and its relevance to our daily life.”

Discussion

The purpose of this paper was to examine pre-service teachers’ mathematical power. Mathematical power is seen as an important factor in developing pre-service teachers’ ability to reason and reflect critically on problems and challenges (NCTM, 2000). Over the past two decades, findings from research have accumulated suggesting a positive relationship between mathematical power and teachers’ commitment to teaching mathematics through creative methods of teaching (Hamshi, 2010; Mohammad, 2011). Several studies have found that mathematical power is correlated with efforts to impact a range of teacher attitudes and behaviors. The triangulation mixed method design was used to better understand the pre-service elementary teachers’ mathematical power in terms of mathematical communication, mathematical connection, and mathematical reasoning at a public university in the eastern province of Saudi Arabia. The purpose of the triangulation mixed method design is to collect diverse but complementary data on the same topic to find a better answers for the research questions (Morse, 1991).

The quantitative data was collected using a MPT. The quantitative study showed that pre-service teachers had low level of mathematical power (M = 4.6197). The quantitative results also revealed that *mathematical communication* have the highest mean score followed by the *mathematical connection* and *mathematical reasoning*. The quantitative results further showed that there was no statistically significant difference between male and female pre-service elementary teachers’ mathematical power (t = -1.200, p = 0.234). These results reiterate findings from early research on mathematical power. Prior research conducted regionally revealed that statistically significant differences in the mathematical power between males and female. For example, Al Rasbi (2004) detected no significant differences in mathematical power between male and female students. Al-Wehaibi (2009) also found that the performance level of students in the mathematical power processes was below the normal level. Such low level could be attributed to the remarkable reliance on the traditional teaching methods (Al-Wehaibi, 2009). These findings support educational initiatives designed to improve teachers’ mathematical power in order to improve their students’ achievement in mathematics. Educators should help to create an appropriate learning environment that encourages students to express their mathematical ideas in a proper way and interact with others. Al-Maawali (2007) emphasized that educators must motivate their students to organize their thoughts on how to deal with mathematical situations so that they have a sense of their mathematical power and the flexibility of mathematics.

The qualitative data clarified and supported the quantitative data. The qualitative data provided the reasons for the participants’ level of mathematical power. The first reason emerged from the participants’ responses was the teacher educators. The participants reported that the educators’ traditional teaching methods do not provide adequate opportunities to help their mathematical power. This finding is consistent with Al- Wahaibi (2009); Baroody and Coslick (1998); and Helioh (2015) who reported that teachers’ traditional methods of teaching weaken the mathematical strength and lead them to depend on others.

The second reason for the participants’ level in mathematical power is the pre-service teachers’ beliefs about mathematics. The pre-service teachers’ responses revealed their negative attitude towards mathematics, which significantly affects their power and interest in mathematics. These results showed that one of the major challenges of learning mathematics is the students' negative beliefs and the low interest towards mathematics (Sukasno, 2016). Students face several challenges in learning mathematics related to the learning of mathematics which negatively affect their ability to communicate about and through mathematics, reason, and connect the ideas in the mathematical ideas and between mathematics and other sciences, problems and making decisions (Kusmaryono, 2007).

The final reason for the participants' level in mathematical power is the content knowledge. Most of the participants believed that the pre-service primary teacher preparation program is very general, and they need more relevant content knowledge. This finding is consistent with Al Sultan (2020) who reported that "teacher preparation programs face the challenge of designing their programs to fit all the demands of different subjects… pre-service elementary teachers need more content knowledge" (p. 9). Thus, this paper suggests that pre-service teachers need more relevant content to help students to learn mathematics successfully and improve their mathematical power and achievement.

Conclusion

Teachers' mathematical power has been suggested to have a powerful influence on improving learner attainment. This paper is unique because it advances our understanding of pre-service teachers' level of mathematical power and the factors that affect such level in Saudi Arabia using mixed method design. The study recommends that teacher preparation program leaders should create new curriculum to improve pre-service teachers' mathematical power. Educators should investigate other factors that could improve pre-service teachers' mathematical power domains including mathematical communication, connection, and reasoning. However, this study has some limitations that should be addressed in future research. First, the data was collected within a specific context. Therefore, the results could not be generalized to other areas. Further studies could be conducted in other parts of the globe. Second, due to the small size of the sample, more conductive teacher preparation programs should be considered. This paper is conceived as a preliminary effort to measure the mathematical power of pre-service elementary teachers. More research is needed to develop tools to improve mathematical power among pre-service teachers. Third, although this study provides insights into the mathematical power pre-service, further longitudinal studies might be needed to detect developments in the level of mathematical power among pre-service teachers over time.

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