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Abstract

Early mathematics content that is taught in elementary school lays the foundation for students' advanced mathematics performance. Thus, researchers show it is important that pre-service elementary teachers build a strong background in numbers and operations, as well as efficacy beliefs in mathematics instruction. This study expands the literature in the investigation of pre-service teachers' efficacy beliefs and mathematical knowledge by making comparisons of pre-service elementary teachers' views of efficacy to their overall ability in computation skills. Results show that elementary pre-service teachers who demonstrated lower scores in efficacy beliefs also had significantly lower computation scores. Implications for teacher preparation are also discussed.

Keywords

efficacy beliefs, computation, mathematics

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Beliefs of Efficacy and Elementary Teachers' Computational Skills

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Abstract: Early mathematics content that is taught in elementary school lays the foundation for students' advanced mathematics performance. Thus, researchers show it is important that pre-service elementary teachers build a strong background in numbers and operations, as well as efficacy beliefs in mathematics instruction. This study expands the literature in the investigation of pre-service teachers' efficacy beliefs and mathematical knowledge by making comparisons of pre-service elementary teachers' views of efficacy to their overall ability in computation skills. Results show that elementary pre-service teachers who demonstrated lower scores in efficacy beliefs also had significantly lower computation scores. Implications for teacher preparation are also discussed.

Key Words: efficacy beliefs, computation, mathematics

Beliefs of Efficacy and Elementary Teachers' Computational Skills

According to the National Mathematics Advisory Panel (NMAP, 2008), students in the United States have poor preparation in solving problems using rational numbers and operations which hinders their mathematical performance in higher level mathematics such as algebra. This is troubling because individuals' mathematical skills account for differences in employment, income, and work productivity more so than their intellectual quotient and reading ability (Rivera-Batiz, 1992). Early mathematics content that is taught in elementary school lays the foundation for students' advanced mathematics performance (Flores, Houchins, & Shippen, 2006; NMAP, 2008; Van Luit & Schoman, 2000). Therefore, it is very important that pre-service elementary teachers build a strong background in numbers and operations as well as efficacy beliefs in mathematics instruction (Hill, Rowan, & Ball, 2005). According to Enochs, Smith, & Huinker (2000) mathematics efficacy beliefs involve two important sets of beliefs: first it is one's personal belief in his or her ability to provide mathematics instruction and second it is one's belief that effective teaching can bring about student learning regardless of external factors such as a student's socio-economic status or culture. The NMAP also states research is needed that investigates teacher preparation in mathematics instruction. Thus, the purpose of this study was to examine the effects of elementary pre-service educators' efficacy beliefs in mathematics and their computational skills.

Reviewing the literature regarding efficacy beliefs in mathematics of pre-service teachers provides insight in teacher preparation for mathematics instruction. Researchers show pre-service teachers' educational experiences (i.e., mentoring and interactions with others), mathematical anxiety, content knowledge, and mathematic instructional knowledge are tied to their beliefs of efficacy to provide mathematics instruction. Mentoring is found to change

efficacy beliefs in a variety of ways (Charalambous, Philippou, & Kyriakides, 2008). The Charalambous et al. (2008) study highlights the changes in efficacy beliefs of 89 pre-service teachers based on their daily interactions when teaching mathematics during their field experiences with peers, mentors, tutors, and children. Specifically, feedback from a mentor who was well respected by the pre-service teacher greatly impacted pre-service teachers' beliefs in their own efficacy. However, a negative influence on efficacy beliefs was reported by pre-service teachers who had significant differences in teaching styles and beliefs than their mentors.

In addition to mentoring impacting efficacy beliefs, mathematics anxiety of pre-service teachers' is found to influence their efficacy beliefs as well. Research indicates that college students who have high levels of math anxiety avoid majors that require numerous mathematics courses. In turn, this avoidance inhibits their mathematical performance (Ashcraft, 2002; Hembree, 1990; Perry, 2004). Kazelskis et al. (2000) define mathematics anxiety as the emotions of anxiety and stress that arise during mathematic lessons, when dealing with numbers in daily life, or when solving mathematics problems.

Swars, Daane, and Giesen (2006) shed light on the influence of mathematics anxiety on pre-service teachers' mathematics teaching efficacy beliefs. Twenty-eight pre-service teachers who were enrolled in a mathematics methods course completed the Mathematics Anxiety Rating Scale (Richardson & Suinn, 1972) and the Mathematics Teaching Efficacy Beliefs Scale (Enochs, Smith, & Huinker, 2000). Pre-service teachers with higher scores of mathematics anxiety demonstrate lower scores of mathematics efficacy beliefs. Based on scores from both scales, four participants were chosen to participate in semi-structured interviews. Results show participants with high mathematics anxiety discussed timed tests and pop quizzes indicating a focus on memorization of mathematics procedural knowledge.

Gresham's (2009) study shows similar findings to Swars' et al. (2006) research on mathematics anxiety and beliefs of efficacy. Pre-service elementary teachers who were enrolled in a mathematics methods course completed the Mathematics Anxiety Rating Scale (Richardson & Suinn, 1972) and the Mathematics Teaching Efficacy Beliefs Instrument (Enochs, Smith, & Huinker, 2000). Similar to Swars et al. (2006), a portion of the participants participated in individual interviews. The pre-service teachers who had lower mathematics anxiety had higher scores for mathematics teaching beliefs of efficacy, demonstrating a negative relationship between mathematics anxiety and efficacy beliefs.

Research also shows that pre-service teachers' knowledge in mathematic teaching methodology impacts pre-service teachers' efficacy beliefs. Ball (1990) explains mathematics instruction is driven by teachers' ability to understand and use mathematical knowledge to carry out the task of teaching which goes beyond the content knowledge that is needed to convey the mathematical algorithm. For example, not only do pre-service teachers need to know the procedures in solving the mathematical problems, they also must know the concepts or the reasons behind the procedures, and how to convey the mathematical content to others.

In a longitudinal study, Swars, Hart, Smith, Smith & Tolar (2007) discover instruction in mathematical pedagogy improves pre-service teachers' efficacy beliefs. The study investigates the mathematics beliefs of efficacy and mathematical instructional knowledge of elementary pre-service teachers who took part in a developmental teacher preparation program which included two courses of mathematics teaching methodology. Results show participants' mathematical pedagogical and teaching efficacy beliefs were low at the beginning of the program. Pre-service teachers significantly increased their personal efficacy beliefs for teaching mathematics as they completed the two courses of mathematics teaching methodology. In addition, the changes in

pre-service teachers' pedagogical and efficacy beliefs carried into participants' student teaching experiences at the end of their program.

Flores, Patterson, Shippen, Hinton, and Franklin (2010) show a relationship between efficacy beliefs and teachers' ability to solve mathematical word problems among both pre-service and in-service teachers. Participants were pre-service and in-service graduate and undergraduate students who were enrolled in elementary (Grades K–6) or middle (Grades 4–8) level teacher preparation programs. Participants who had higher beliefs of efficacy scores in teaching mathematics also showed higher scores in problem solving skills.

Further exploring the relationship between pre-service teachers' efficacy beliefs and their mathematical content knowledge, Bates, Kim, and Latham (2011) compared 89 pre-service early childhood teachers' beliefs of efficacy measures to their mathematical performance. Participants were given the Mathematics Self-Efficacy Scale, the Mathematics Teaching Efficacy Beliefs Instrument (Enochs, et al., 2000) and the Illinois Certification Testing System Basic Skills Test. Bates and colleagues' results indicate that pre-service educators' mathematics beliefs of efficacy were positively related to their performance on the Illinois Certification Testing System Basic Skills Test.

Research has demonstrated the need to develop teachers' mathematics beliefs of efficacy considering its relation to pre-service teachers' educational experiences, mathematical anxiety, mathematical content knowledge, and mathematic instructional knowledge. However, another important aspect of teaching elementary mathematics involves number sense (NCTM, 2000; NMAP, 2008). The National Council of Teachers of Mathematics (NCTM) define number sense as “moving from the initial development of basic counting techniques to more sophisticated understandings of the size of numbers, number relationships, patterns, operations, and place

value” (2000, p.79). Number sense extends to numbers written in fraction, decimal, percent, and exponential forms and encompasses commutative, associative, and distributive properties, as well as knowing how to apply these properties to solve problems (NMAP, 2008). With regard to elementary pre-service preparation, pre-service teachers must build detailed understanding of how number size, relationships of numbers, patterns, place value, estimation, and number operations are interrelated, and critically analyze mathematical concepts prior to and beyond the grade level they are assigned to teach (NMAP, 2008). Therefore, the purpose of this research is to expand upon the literature in the investigation of pre-service teachers’ efficacy beliefs and mathematical knowledge by making comparisons of pre-service elementary teachers’ views of efficacy beliefs to their overall ability in computation skills and their number sense knowledge. The following questions guided the study:

- 1) To what extent do differences exist in pre-service teachers’ computation and/or number skills based on their personal mathematical teaching efficacy beliefs?
- 2) To what extent do differences exist in pre-service teachers’ computation and/or number skills based on their efficacy beliefs in mathematical outcome expectations?
- 3) To what extent is there a relationship among pre-service teachers’ number sense and computational skills?

Methodology

Participants

Data were gathered from a previous study on general and special education teachers’ computational and number sense abilities (Hinton, Flores, Shippen, Kraska & Curtis, 2011). A total of 113 pre-service graduate and undergraduate students enrolled in either a general or

special education elementary level program participated in the study. The criteria in which participants were chosen were (a) participants had to be enrolled in an elementary general education or special education program, (b) participants had to have less than one year of experience, and (c) participants indicated that they planned to teach elementary aged students (K-Grade 5) once they graduated from their college program. Pre-service teachers were recruited through both graduate and undergraduate instructional methods classes at a large and a medium sized university in the southeast region. The largest demographic group was White females enrolled in an undergraduate general education program and under the age of 29. Table 1 outlined the characteristics of the participant sample.

Table 1

Participant characteristics

Gender	#	Culture	#	Age	#	Degree Program	#
Male	4	African American	9	18–20	42	UG General	80
Female	109	Latino/a	0	21–29	70	UG Special	20
		White	104	30–39	1	M-Alt General	1
		Asian	0	40–49	0	M-Alt Special	3
						Masters General	1
						Masters Special	8

Note. UG = undergraduate program, M-Alt = alternative 5th year graduate program

Survey Instruments

Computational knowledge was surveyed using the calculation subtest of the Woodcock Johnson III (WJIII; Woodcock et al., 2001). The Woodcock Johnson was used to gather a standardize score that could be compared to national averages based on participants' characteristics such as age as well as a general score of their ability to perform mathematical computations. Woodcock et al. (2001) stated the initial test items require one to write single numbers. The remaining items required the individual to perform addition, subtraction, multiplication, division, combinations of the basic operations, and geometric, trigonometric,

logarithmic, and calculus operations which involved negative numbers, percentages, decimals, fractions and whole numbers (Woodcock et al., 2001). Woodcock et al. (2001) reported a math calculation subtest median reliability score of .89 in the adult range.

Number sense skills were measured through problems based on an instrument that examined strategies used by adults to solve computational problems based on number sense components (Yang, 2009). The number sense components were (a) understanding the meaning of numbers, operations, and their relationships, (b) recognizing relative number size, (c) developing and using benchmarks appropriately, and (d) judging the reasonableness of a computational result by using the strategies of estimation. There were a total of 12 number sense questions. Respondents were asked to choose an answer to the problem and then state how they solved the problem. This current study modified Yang's interview instrument into an open ended questionnaire in which respondents were to solve the number sense problems. Validity measures were taken by distributing the questionnaire to three teachers to review. All three teachers had at least a master's degree or higher from an accredited university with an average of 5 years of experience in teaching mathematics in elementary or middle school. The reviewers were asked to score each problem for each skill area according to its relevance to the content using a 4-point scale to avoid having neutral and ambivalent midpoint. The item relevance continuum used was 1= not relevant, 2= somewhat relevant, 3= quite relevant, and 4= highly relevant. Then for each item, the item-level content validity index (I-CVI) was computed as the number of experts giving a rating of 3 or 4 (thus dichotomizing the ordinal scale into relevant and not relevant), divided by the total number of experts (Lynn, 1986). The I-CVI for the pool items was calculated as 1.00 for number sense. Reliability was also examined. The researcher administered the three assessments to 13 college level students from a major four-year

university. The assessments were untimed. Results from the internal consistency test revealed Cronbach's Alpha Coefficient of $r = .69$.

Perceived efficacy of one's ability to teach mathematical knowledge was measured using The Mathematics Teaching Efficacy Beliefs Instrument (MTEBI; Enochs, et al., 2000). The MTEBI consists of 21 items and measures two constructs which are one's views on their personal efficacy to teach mathematics (Personal Mathematics Teaching Efficacy subscale) and one's views on their beliefs that effective teaching can bring about student learning regardless of external factors (Mathematics Teaching Outcome Expectancy subscale). There are thirteen items on the Personal Mathematics Teaching Efficacy subscale and 8 on the Mathematics Teaching Outcome Expectancy subscale. The instrument has a Likert-type scale with five response categories including strongly agree, agree, uncertain, disagree, and strongly disagree. Possible scores on the Personal Mathematics Teaching Efficacy subscale range from 13 to 65; Mathematics Teaching Outcome Expectancy subscale scores range from 8 to 40. Reliability analysis produced an alpha coefficient of .88 for the Personal Mathematics Teaching Efficacy subscale and an alpha coefficient of .75 for the Mathematics Teaching Outcome Expectancy subscale ($n = 324$). Confirmatory factor analysis indicated that the two subscales were independent (Enochs et al., 2000).

Procedures

Information about pre-service teachers' computational knowledge, efficacy beliefs, and numbers sense skills were gathered through a survey. Three hundred surveys were given out to all pre-service teachers who are majoring in education in general. Two-hundred and thirty surveys were completed yielding a 77% completion rate. Of the 230 surveys that were completed, 113 participants met the criteria of the study.

The surveys and questionnaires were distributed in the form of a packet and completed by graduate and undergraduate students enrolled in general education and special education courses specific to methods within each major. All surveys and questionnaires were numbered and participants did not write their name on any items provided to ensure confidentiality. Everyone was provided a letter explaining the risks to participants, their rights as participants, and who to contact regarding any questions or concerns. Participants chose to complete or not complete the packet. The background questionnaire was completed first so that the mathematics tasks within the survey did not interfere with the participants' answers. Participants completed the computation knowledge survey, efficacy beliefs survey, and number sense questionnaire using pencil and paper. All participants completed the math efficacy beliefs survey first. No time limit was assigned and the order of the math knowledge and number sense portions of the survey packet was counterbalanced to limit any one variable receiving a higher score due to participant fatigue or order effects. Therefore, half of participants received the math knowledge portion first then the number sense questionnaire, and half of participants received the number sense questionnaire first, then math knowledge survey.

Pre-services teachers' beliefs about efficacy were grouped in order to make comparisons among their perceptions of efficacy and mathematics computation and number senses scores. Scores for pre-service educators' perceptions of teaching efficacy were grouped accordingly: group one consisted of scores 52 and above indicating the participants viewed themselves as effective in teaching mathematics, group two consisted of scores between 39 and 51 indicating participants viewed themselves as somewhat effective in teaching mathematics. Finally, group three consisted of scores below 38 indicating they did not view themselves as effective in teaching mathematics.

Scores for pre-service educators' teaching outcome expectancies were grouped accordingly: group one consisted of scores 32 and above demonstrating participants believed effective teaching can bring about student learning regardless of external factors. Group two consisted of scores 25 to 31 showing participants somewhat believed effective teaching can bring about student learning regardless of external factors. Finally, group three scored 24 and below demonstrating that participants did not believe effective teaching can bring about student learning regardless of external factors.

Results

Data regarding efficacy beliefs, computational skills and number sense were analyzed using a Multivariate Analysis of Variance (MANOVA). Results were consistent with previous research indicating a significant difference between pre-service educators' efficacy beliefs and computational skills (Wilks' $\Lambda = .905$, $F(4, 202) = 2.59$, $p < .05$). Univariate ANOVA analysis was conducted as a follow up test. ANOVA results indicate that computational skills significantly differed based on participants' efficacy beliefs in outcome expectancies ($F(2, 202) = 4.92$, $p < .05$). Specifically, Post Hoc analyses show that participants with the lower scores of 24 and below for efficacy beliefs of mathematics expectancies also demonstrated lower computation scores (Fisher's LSD, $p < .05$). Therefore, the elementary pre-service teachers who indicated they did not believe instruction in mathematics can bring about student learning regardless of external factors also had significantly lower computation scores than the pre-service teachers who indicated they somewhat or strongly believed mathematics instruction can bring about student learning. Means and standard deviations for computational scores and efficacy outcome expectancies are shown in Table 2. Even though a significant difference was found in efficacy beliefs regarding learning outcomes, a significant difference was not found

among pre-service teachers' efficacy beliefs of their personal teaching effectiveness and their computational or number sense skills.

Table 2

Means and Standards Deviations of Computation by Mathematics Teaching Outcome Efficacy

Efficacy Levels for Outcome Expectations	Computation Mean	Computation Standard Deviation
MTOE scores 32 and Above	27.6	3.50
MTOE scores 25 to 31	29.3	4.27
MTOE scores 24 and Below	26.7*	4.13

* statistically significant at .05

The relationship between number sense and computational skills was analyzed using a Pearson product-moment correlation coefficient. There was no correlation between pre-service teachers' computational and number sense skills ($r = -.003$, $N = 111$, $p = .978$). Therefore pre-service teachers' ability to solve computational problems was not related to their number sense skills.

Discussion

This study explored comparisons among future elementary education teachers' efficacy beliefs and their computation abilities and number sense skills. The following questions guided the study:

- 1) To what extent do differences exist in pre-service teachers' computation and/or number skills based on their personal mathematical teaching efficacy beliefs?
- 2) To what extent do differences exist in pre-service teachers' computation and/or number skills based on their mathematical outcome expectations?

- 3) To what extent is there a relationship among pre-service teachers' number sense and computational skills?

Overall differences were found in pre-service teachers' efficacy beliefs and their computation abilities. In particular, pre-service teachers who indicated an efficacy belief that effective teaching does not bring about student learning regardless of external factors had significantly lower computational scores. This finding reflects previous research (Bates et al., 2011; Flores et al., 2010) in which mathematical performance was positively related to efficacy beliefs. Perhaps pre-service educators who demonstrated lower scores on mathematical performance tests did not hold the view that instruction could change student performance because their frame of reference indicates changes in outcomes would be minimal. Therefore, it was very important to consider Swars et al. (2007) research which found teacher preparation programs with a focus on pedagogy improve pre-service teachers' efficacy beliefs.

Even though significant differences were found in efficacy beliefs of outcome expectations and pre-service elementary educators' computational skills, differences were not found in number sense abilities or in pre-service teachers' efficacy beliefs in personal teaching. It is possible this finding pointed to the inexperience of pre-service teachers when it comes to the provision of mathematics instruction. Perhaps more research that sheds light on pre-service elementary teachers' field experiences while providing mathematics instruction can uncover more ways of improving pre-service teachers' beliefs of personal teaching efficacy.

Lastly, findings suggest that elementary pre-service teachers' number sense skills and computational abilities were not found to be related. This finding is consistent with research that stated individuals can solve mathematical problems using procedures; however they may not know the concepts or the reasons behind the procedures (Ball, 1993; Ball, Hill, & Bass, 2005,

Yang, 2009). This is very important considering Ball's research that shows teachers' content knowledge of mathematics must go beyond understanding the procedures for solving problems to a deep understanding of the concepts or the reasons behind the procedures, as well as how to convey the mathematical content to others.

Limitations and Future Research

Findings of this study demonstrate the importance of elementary pre-service teachers gaining mathematical content knowledge as well as developing pedagogy knowledge. Limitations for the study include the lack of variation in the research sample. Most of the participants were White females, indicating a limited variation in demographics of the sample. Additionally, pre-service teachers were not asked to explain why and how they chose their answers to the mathematical problems. Doing so would give insight that could assist in teacher preparation for mathematical content. Additionally, this study addressed only skills and beliefs of efficacy of pre-service elementary educators. Continued investigation is needed regarding mathematics anxiety and pre-service teachers who seek to provide higher level mathematics instruction as well. It is possible that valuable information may be gathered examining differences among elementary and secondary pre-service educators' numeracy skills, computational abilities, and anxiety. Future research could include investigating in-service teachers' number sense abilities along with beliefs of teaching efficacy and outcome expectations. Also future research needs to be conducted that examines further how teachers' perceptions of teaching efficacy and outcome expectations change along with numerous ways of increasing pre-service teachers' content knowledge of mathematics.

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