Math and Technology Leadership Academy: Impact on Mathematics Teacher Sense of Efficacy

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Abstract

The Math and Technology Leadership Academy (MTLA) was a three-year initiative awarded by Toyota USA Foundation to advance elementary teachers' instructional techniques in mathematics, leadership, and technology. Over the three years, fourteen teacher participants of grade levels spanning from kindergarten through sixth grade engaged in three mathematics pedagogy courses and monthly seminars. Teacher participants then implemented the innovative math strategies into their classrooms. This paper will discuss the design of MTLA and the research plan and results. The study found significant results from the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) in the Self-Efficacy construct. After three years of participation in MTLA, the teachers in the MTLA demonstrated significantly higher self-efficacy than their control teacher of elementary mathematics; however, both groups of teachers demonstrated similar beliefs about outcomes expectations or the belief that effective mathematics instruction can affect student learning outcomes.

Introduction

Elementary teachers need advanced instructional skills in the areas of mathematics and technology. More importantly, elementary mathematics teachers need to believe that they can increase student learning in mathematics. After receiving their undergraduate degree and teaching certification, new teachers often do not have time to keep abreast of the latest research in strategies and technology integration. The field of mathematics education is continuously evolving with the integration of technology. If teachers are provided appropriate professional development about mathematics and technology integration, with chances to practice, discuss, and reflect on experiences, their beliefs in their own abilities to increase student learning in mathematics also has the potential for growth.

Teacher efficacy is the teacher's belief in their own ability to guide their students to success or increased learning in mathematics. Teachers with higher efficacy are planners, more resilient through failure, and more open-minded and supportive with students. According to Hattie's meta-analysis of factors impacting student achievement (2012, pp. 22-26), teacher efficacy had the largest impact on student achievement, beyond teacher-student relationships, home environment, or parental involvement. Teachers with low levels of efficacy are less likely to challenge students, implement new ideas, or persevere through difficulties.

Theoretical framework

Based on Bandura's (1986) social theory of learning, Enochs, Smith, and Huinker (2000) define self-efficacy as "*when people not only expect specific behavior to result in desirable outcomes, but they also believe in their own ability to perform the behaviors*" (pp. 194-195). According to Bandura (1977), the two components of self-efficacy are *efficacy expectations* and *outcome expectations*, which he defines as follows:

> *An outcome expectation is defined as a person's estimate that a given behavior will lead to certain outcomes. An efficacy expectation is the conviction that one can successfully execute the behavior required to produce the outcomes. Outcome and efficacy expectations are differentiated, because individuals can believe that a particular course of action will produce certain outcomes, but if they entertain serious doubts about whethe*r they can perform the necessary activities such information does not influence their behavior (p. 193).

Bandura (2001) further explains perceived self-efficacy as follows:

- Perceived self-efficacy plays a causal role in affecting adaptation and change.
- Self-efficacy beliefs influence whether people think pessimistically or optimistically and in ways that are self-enhancing or self-hindering.
- Efficacy beliefs play a central role in the self-regulation of motivation through goal challenges and outcome expectations.
- It is on the basis of self-efficacy beliefs that people choose what challenges to undertake, how much effort to expend in the endeavor, how long to persevere in the face of obstacles and failures, and whether failures are motivating or demoralizing.
- The likelihood that people will act on the outcomes they expect prospective performances to produce depends on their beliefs about whether they can produce those performances.

Those with high self-efficacy succeed well beyond their capacities, while people with low self-efficacy might underperform due to inaccurate view of their abilities (Bandura, 1982). Thus, perception becomes reality as a person's beliefs heavily impact their performance level. Pajares (1992) stated, "*Beliefs are far more influential than knowledge in determining how individuals organize and define tasks and problems and are stronger predictors of behavior*" (p. 311).

Teachers are a primary factor in the academic success of students (Tucker & Strange, 2005). Teacher efficacy is connected to positive outcomes including student achievement and student motivation. Therefore, teacher efficacy is crucial for effective mathematics instruction (Newton, Leonard, Evans, & Eastburn, 2012). Teachers who indicate that they dislike mathematics are more likely to spend less time planning or teaching the subject (Trice & Ogden, 1986). In contrast, teachers with high teaching mathematics efficacy more frequently engage students in higher-level thinking tasks and student-centered instruction, which correlates with higher achievement (Swars, Hart, Smith, Smith, & Tolar, 2007). Research reveals that teachers who possess a high sense of efficacy are more effective mathematics teachers than teachers with a lower sense of efficacy (Swars, 2005). Teachers who have high self-efficacy and thus confidence in their teacher capacities focus more intently on academic content in the classroom (Gibson & Dembo, 1984), experiment with new teaching strategies (Haney, Lumpe, Czerniak, & Egan, 2002), persevere more with students struggling to learn (Haney et al., 2002), and seek additional professional learning opportunities (Gersten, Chard, & Baker, 2000) in comparison to teachers with low self-efficacy.

Teachers with a high sense of efficacy have a positive disposition toward math, which can strongly affect students' opinions about mathematics. Teacher self-efficacy has been shown to have a direct connection to students' academic performance (Dembo & Gibson, 1985; Pajares, Usher, & Johnson, 2007; Woolfolk & Hoy, 1990). Graham, Harris, Fink, and MacArthur (2001) contend that teachers' efficacy is "*one of the few teacher characteristics that reliably predicts teacher practice and student outcomes*" (p. 178). In the field of math, teaching efficacy refers to one's beliefs in their ability to teach mathematics effectively (Enochs et al., 2000).

Related studies using the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI)

The Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) has been widely utilized with pre-service teacher populations to measure self-efficacy (Enochs et al., 2000). However, the instrument has also been used with determining status and growth of self-efficacy and outcome expectancy with in-service teachers.

Research concerning how professional development improves elementary teachers' mathematics teaching is critically important. Good (2009) pursued the goal of designing an effective professional development model for her own district's elementary mathematics teachers. Specifically, she was examining how to design professional development that would deepen mathematics content knowledge while also decreasing mathematics anxiety. She referred to "mathematics teacher efficacy" as how to indicate a teacher's belief in their competency to positively impact a student's ability and motivation to learn mathematics content. Good (2009) stated that Swars, Daane, and Giesen (2006) found pre-service teachers with low levels of math anxiety had stronger mathematics teacher efficacy. Similarly, Good's (2009) found that the in-service teachers produced similar results with the majority reporting low math anxiety and high levels of mathematics teacher efficacy. She also found that the in-service teachers had stronger beliefs in their own effectiveness as mathematics teacher (personal math teacher efficacy) than they did in mathematics teaching in general (math teacher outcome expectancy).

Another study by Barta and Ostrogorsky (2004) incorporated MTEBI with in-service teachers to determine the effects on a new mathematics curriculum on mathematics teaching efficacy at elementary and middle school levels. The results showed that, with using the new curriculum, teachers increased in both their personal teaching efficacy and in mathematics teacher outcome expectancy. The comparison group of teachers showed increases as well, but no results were statistically significant.

A third study by Christie, Rillero, Cleland, Wetzel, Zambo, and Buss (2001), used the MTEBI to measure the impact of a teacher development project where teachers were designing mathematics and science units. The results showed a significant increase in the participants' personal mathematics teaching efficacy and in their mathematics teaching outcome expectancy.

Current study: Math and Technology Leadership Academy

To examine how to impact teacher efficacy, the Math and Technology Leadership Academy (MTLA) sponsored by Toyota was designed to identify and support in-service elementary teachers wanting to expand their capacities in the areas of mathematics, technology, and leadership.

Through MTLA, teachers would learn, practice, and implement new strategies for integrating digital tools to enhance the learning in their math classroom. In the following section, we explain the methodology used in the research study.

Methodology

MTLA was planned with the idea of impacting an entire county of elementary schools near the south-central university community. One teacher from each of the schools was asked to apply. The initiative focused on the following goals:

1. Bolster teacher efficacy in math and technology.
2. Raise student achievement in math and technology.
3. Develop a national model for teacher preparation and professional development.
4. Boost family involvement in math and technology education.
5. Increase access to math and technology opportunities for diverse populations.

The MTLA was designed as a three-year initiative. Teachers completed an application and were interviewed. Initially, 19 teachers were selected (one from each elementary school); however, 14 MTLA teacher participants, termed Scholars, finished the program. In the first year of the program, three types of pre-assessments were administered to two groups: the MTLA Scholars and a control teacher at each Scholar's school. The assessments included leadership style and qualities, math efficacy surveys, and technology integration level survey. Three graduate courses were developed and taught: ELED 571 – Leadership, Math and Technology, ELED 572 – Math and Technology Methods for Diverse Learners, and ELED 573 – Math and Technology Assessments, Interventions, and Success. MTLA Scholars prepared Math, Technology, and Leadership Growth Plans that included a description of their strengths and growth area related to the Association of Mathematics Teacher Educators (AMTE) Standards for Elementary Mathematics (2013) and International Society for Technology Education (ISTE) Standards for Educators (2017). In the Leadership Growth Plans, teachers identified a plan of action, impact and evidences for each growth area as well as a description of activities or programs that they would implement over the next two years. As a requirement, each Scholar's plan was required to include at least one local, state, or national conference presentation as well as implementation of a math and technology project with students at the local Housing Authority. During the first year the co-directors held monthly seminars that focused on course work, math strategies, technology implementation strategies, and developing the professional growth plan.

In year two, Scholars wrote mini-grants to fund their activities and programs to implement their Math, Technology, and Leadership Growth Plan. The monthly seminars were continued to focus on training in iPad apps and instructional practices, provide time to present Housing Authority projects, and highlight Scholars' accomplishments from presentations, implemented school programs, and online blogs. The co-directors visited each Scholar in their school to observe their progress and achievements. The Elementary Mathematics Specialist Endorsement was created, and five Scholars completed that endorsement which included an additional two mathematics content courses above and beyond the grant commitment. Interim assessment data was collected using the same three assessment instruments for the pre-assessment.

The MTLA was completed and celebrated in the third year. The Scholars completed their Professional Growth Plan activities, reported on those projects on their blog website, presented at a state conference, and completed teaching projects at the Housing Authority. The MTLA website was launched. The final assessment data was collected using the same three assessment instruments. The co-directors and one consultant began analysis of this data. Two seminars were conducted in September and November focusing on iBooks training and technology integration in elementary math classrooms. A final MTLA Celebration was held in February 2013, marking the end of the three-year academy program.

Instrumentation

Utilizing Bandura's (2001) social cognitive theory, the Mathematics Teaching Efficacy Belief Instrument (MTEBI) measures mathematics efficacy beliefs in teachers (Enochs et al., 2000). The MTEBI consists of 21 items that assess two subscales: Personal Mathematics Teaching Efficacy (PMTE) (13 items) and Mathematics Teaching Outcome Expectancy (MTOE) (8 items). The *MTOE*, or outcome expectancy subscale, measures teachers' beliefs about mathematics teaching in general; whereas the *PMTE*, or self-efficacy subscale, measures their beliefs about their own math instruction. The reliability analysis of the instrument produced PMTE subscale with an alpha coefficient of 0.88 and the MTOE subscale with and alpha coefficient of 0.75 (n=324). Confirmatory factor analysis indicated that the two subscales are independent scales supporting the construct validity of the MTEBI. Scores on PMTE range from 13-65; scores on MTOE range from 8-40 (Enochs et al., 2000). PMTE items are connected to Self-efficacy, while MTOE items are connected to Outcome Expectancy. Table 1 shows sample items to illustrate the difference (Enochs et al., 2000).

This MTEBI instrument was administered to two groups:

1. The MTLA Scholars (n=14), and
2. The control teacher at each school (another teacher at the Scholar's school who was in the same grade level but not participating in MTLA) (n=13).

Teachers in both groups had varying years of teaching experience. Additionally each MTLA and paired control teacher were teaching the same content provided by the district.

The MTEBI instrument was administered three times:

1. The beginning of the first year of the program (September 2010),
2. Fall of the second year of the program (September 2011), and
3. Fall of the third year of the program, the conclusion of the initiative (December 2012).

Table 1: PMTE and MTOE Sample Items

PMTE Sample Items	MTOE Sample Items
I will continually find better ways to teach mathematics. (Item 2)	When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort. (Item 1)
Even if I try very hard, I will not teach mathematics as well as I will most subjects. (Item 3)	When the mathematics grade of students improves, it is often due to their teacher having found a more effective teaching approach. (Item 4)
I know how to teach mathematics concepts effectively. (Item 5)	If students are underachieving in mathematics, it is most likely due to ineffective mathematics teaching. (Item 7)
I will not be very effective in monitoring mathematics activities. (Item 6)	The inadequacy of a student's mathematics background can be overcome by good teaching. (Item 9).
I understand mathematics concepts well enough to be effective in teaching elementary mathematics. (Item 11)	Students' achievement in mathematics is directly related to their teacher's effectiveness in mathematics teaching. (Item 13)
I wonder if I will have the necessary skills to teach mathematics. (Item 17)	The teacher is generally responsible for the achievement of students in mathematics. (Item 12)
When a student has difficulty understanding a mathematics concept, I will usually be at a loss as to how to help the student understand it better. (Item 19)	When a low-achieving child progresses in mathematics, it is usually due to extra attention given by the teacher. (Item 10)
I do not know what to do to turn student on to mathematics. (Item 21)	If parents comment that their child is showing more interest in mathematics at school, it is probably due to the performance of the child's teacher. (Item 14)

Research questions

Utilising the MTEBI, the researchers sought to determine the impact of the MTLA program on Scholar as compared to their respective peers. Two research questions emerged.

1. What was the impact of participation in MTLA of the Scholars compared to the control group in the area of Personal Mathematics Teaching Efficacy (PMTE)?
2. What was the impact of participation in MTLA of the Scholars compared to the control group in the area of Mathematics Teaching Outcome Expectancy (MTOE)?

Results and discussion

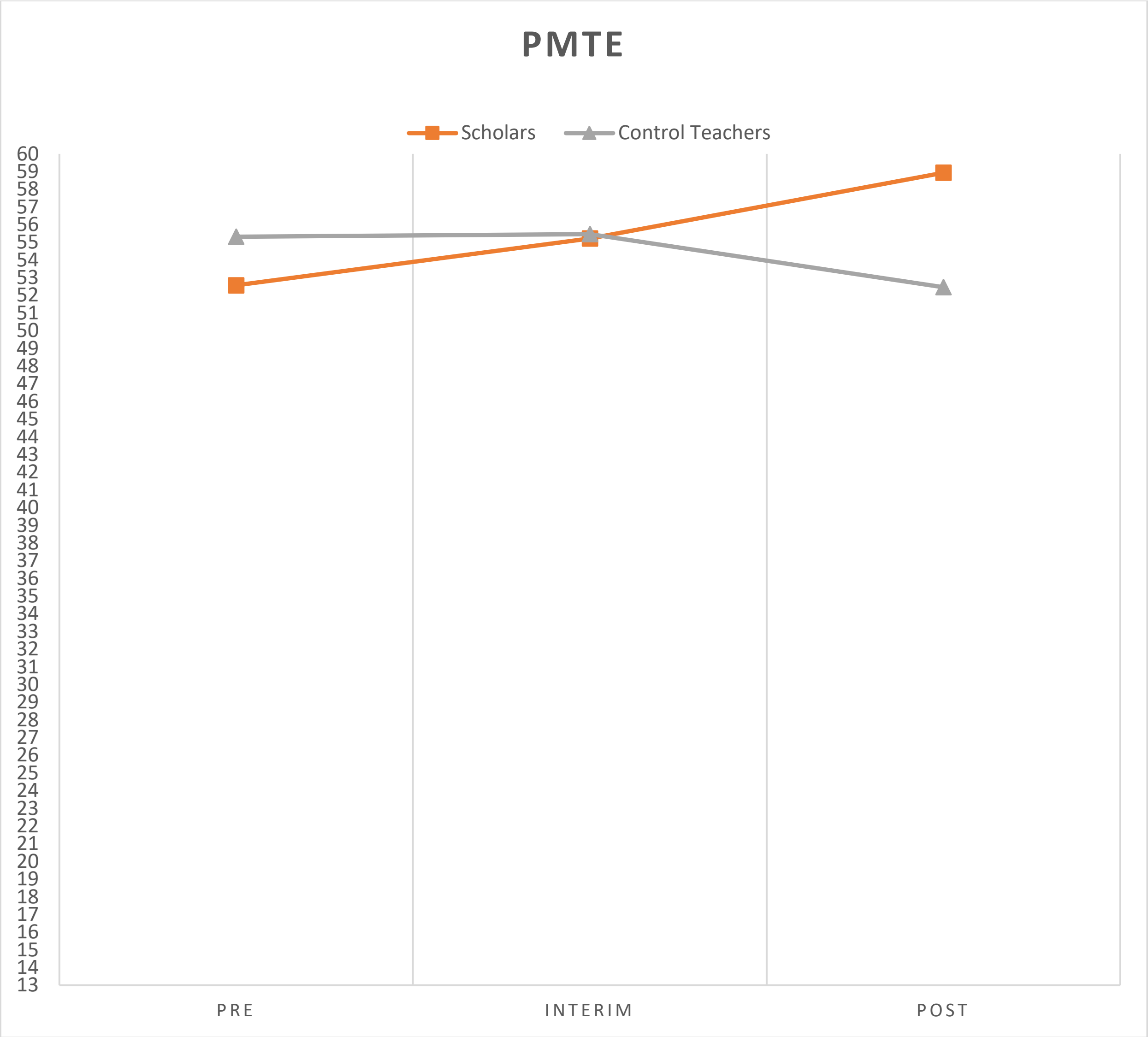
Research question 1

To answer the question, "What was the impact of participation in MTLA of the Scholars compared to the control group in area of Personal Mathematics Teaching Efficacy (PMTE)?", the first MTEBI subscales, Personal Mathematics Teaching Efficacy (PMTE), also known as 'self-efficacy' scale, was used. The results revealed significant differences at the .05 significance level. The results were analysed using a three-way ANOVA with repeated measures on one factor. To do this, a Group X Time interaction was used which was significant, $F(4,76)=2.63$, $p<.05$. However, the Scholars group did display significant increase in PMTE scores across time, $F(2,26)=10.70$, $p<.05$. Post-hoc contrasts revealed that the Scholar group had significantly higher scores at the interim measure, $F(1,13)=7.42$, $p<.05$, and the post measure, $F(1,13)=14.00$, $p<.05$, when compared to the initial measure. Table 2 displays the means, by group, for each of the three PMTE measurement intervals, while Figure 1 displays the results.

These results indicate that MTLA Scholars believe that he or she can teach elementary mathematics effectively while their control teacher counterparts in the same school are not as confident that they can teach elementary mathematics effectively. Throughout the program, Scholars were exposed to math problems, identifying common misconceptions, and innovative teaching strategies. The researchers concluded that these experiences led to increased math content knowledge and more advanced mathematics instructional skills in the MTLA Scholars; thus, significantly higher PMTE scores.

Table 2: Personal Mathematics Teaching Efficacy Results

Group	N	Initial PMTE Score (Range 13-65)		Interim PMTE Score (Range 13-65)		Post PMTE Score (Range 13-65)	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Scholars	14	52.57	5.26	55.21	3.45	58.93	4.08
Control Teachers	13	55.31	5.30	55.46	6.84	52.46	11.27



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Scholars indicated in their final reflections their personal changes in beliefs and confidence in teaching mathematics as a result of participating in the program. Comments included:

> *The confidence I gained in myself and my abilities has made me a better teacher and a better person. I use the skills and tools I learned through MTLA everyday* (Participant 1).

> *MLTA has changed my math attitude. Due to my new found excitement, my knowledge base has grown greatly which has increased my math confidence as well* (Participant 3).
>
> *I now have a feeling of confidence as a leader in my school. I have a vision of excellence in math and technology, not only for my classroom but for my entire school* (Participant 7).
>
> *I now feel more confident in my teaching of math, and I also feel that I now incorporate technology into multiple lessons and activities each week* (Participant 13).

Research question 2

The second subscale of the MTEBI, Mathematics Teaching Outcome Expectancy (MTOE), was used to test the second research question, "What was the impact of participation in MTLA of the Scholars compared to the control group in the area of Mathematics Teaching Outcome Expectancy (MTOE)?" Table 3 displays the means by group for the three Mathematics Teaching Outcome Expectancy (MTOE), or "outcome expectancy," measurement intervals. Figure 2 displays the results for MTOE. The results were analyzed using a three-way ANOVA with repeated measures for one factor. To do this, Group X Time interactions, which was non-significant, resulted in $F(4, 76)=1.04$, $p>.05$. The test for simple effects shows that the mean MTOE scores for the two groups were not significantly different over time: Scholars $F(2,26)=1.13$, $p>.05$; Control Teachers $F(2,24)=1.18$, $p>.05$.

Mathematics Teacher Outcome Expectancy is the belief that effective teaching will produce positive student learning outcomes. In other words, increased student learning or mathematics scores is a result of effective teacher instruction. While the MTLA Scholar's scores were higher than the Control teachers' scores, the two groups of scores for this subscale were not significantly different indicating that teachers have similar ideas about the impact of effective mathematics instruction on student learning.

Table 3: Mathematics Teaching Outcome Expectancy Results

Group	N	Initial MTOE Score (Range 8-40)		Interim MTOE Score (Range 8-40)		Post MTOE Score (Range 8-40)	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Scholars	14	29.92	2.61	30.00	3.41	30.85	2.68
Control Teachers	13	29.69	2.39	29.61	2.29	27.69	6.01

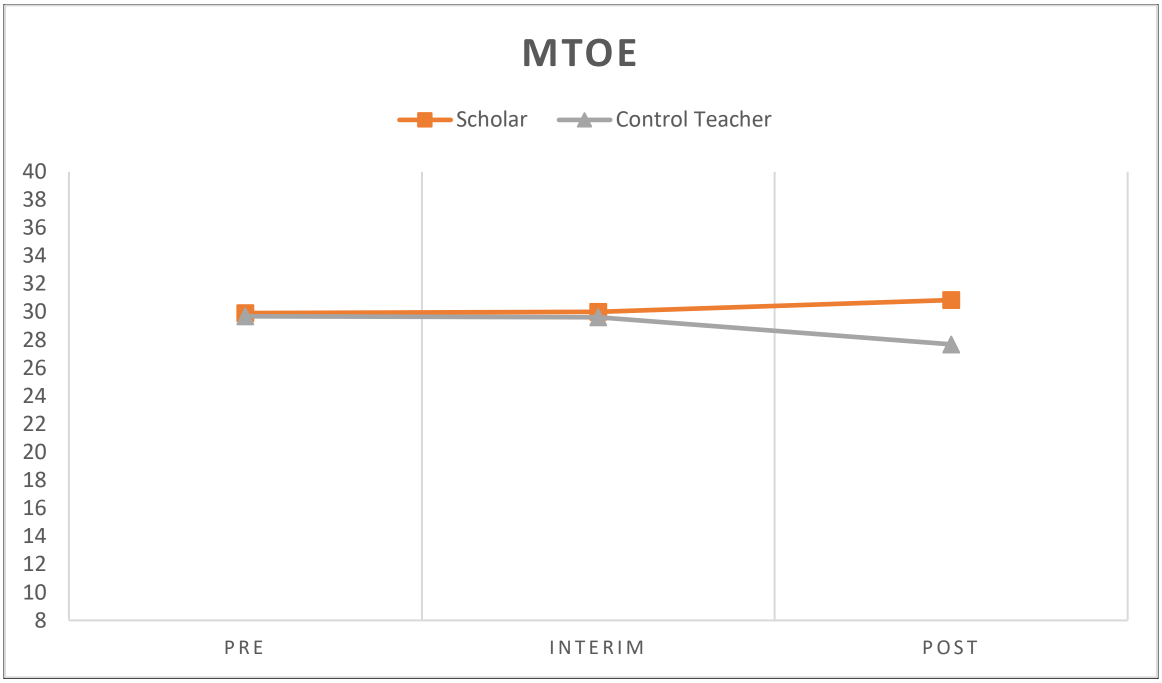

Figure 2: Mathematics Teaching Outcome Expectancy Results

These results are not surprising. Per the PMTE significant results, The MTLA Scholars are more confident than the control teachers that they can teach elementary mathematics effectively to produce student learning outcomes. However, both groups of teachers believe that effective teaching can produce positive student learning outcomes in mathematics, regardless of who teaches them. These results confirm the findings of Good (2009) who also found that the in-service teachers' mean scores from pre- to interim- to post- increased more in relation to personal mathematics teacher efficacy (PMTE) than they did in relation to mathematics teaching in general (mathematics outcome expectancy (MTOE).

In retrospect, MTLA, by design, included more of a focus on mathematics teaching self-efficacy (PMTE) increasing opportunities versus mathematics teaching outcome expectancy (MTOE). Bandura and others make the point that self-efficacy has more of an effect on teacher's mathematics instruction than outcome expectancy. As stated earlier, those with high self-efficacy tend to succeed well beyond their limits, while those with low self-efficacy may underperform due to inaccurate view of their abilities (Bandura, 1982). Pajares (1992) shared that beliefs are highly influential in determining a person's approach to organizing and performing tasks, while serving as a strong predictor of behavior.

Limitation of study

One limitation of the study is the sample size. However, due to the constraints of the study and grant, the sample could not be larger. The grant provided funding for only one teacher from each school in the county and city, thus the reason for limited sample size.

Implications for future research

Further research should focus on how efficacy beliefs influence teaching practice and particularly subsequent student achievement. Exploration of how high mathematics teaching efficacy is developed in pre-service teachers and practicing teachers is needed. This MTLA initiative serves as a model for how to impact in-service teachers in mathematics self-efficacy. However, the area of Mathematics Teacher Outcome Expectancy needs further research in two areas. First, further research is needed to identify interventions that improve outcome expectancy. The authors recommend that practicing teachers be given more opportunities for growth in self-efficacy and outcome expectancy improvement. Through an initiative like MTLA replication, self-efficacy does improve. Second, as seen in the results for MTOE, the MTLA scholars remained consistent in their efficacy throughout the initiative, while the control group had a slight decline in efficacy. Researchers suggest the need for further study to understand the factors or barriers to teacher growth in MTOE subscale over time.

Although we can reflect and understand how this area was not impacted as much as the Self-Efficacy, improving the Outcome Expectancy angle is also needed. However, further research also needs to be done and modifications made to MTLA if outcome expectancy is an important element of focus.

Conclusion

With many teachers eager to expand their content knowledge and ability to engage students in mathematics, teachers want to participate in professional learning initiatives centered on research-based elementary mathematics instruction. Ekawati and Kohar (2016) contend, "*teachers need to coordinate the knowledge gained from teacher professional development program and transform to the classroom practice*" (p. 2). Professional development with an innovative approach should focus on using contextual experiences for the teachers to construct new knowledge (Campbell, 2012). With follow-up workshops to discuss successes, challenges, and experiences, community can be created around the teachers and administrators. The teachers can then use reflection activities to share and discuss their students' mathematics achievement and what they will do for continuous improvement. Teachers should experience professional development as "*active learners instead of passive receivers in building their own understanding*" (Ekawati & Kohar, 2016, p. 12).

During the three years of the Math and Technology Leadership Academy Initiative, the MTLA Scholars demonstrated growth in elementary mathematics teaching self-efficacy. The initiative gave opportunities to come together as leaders in a community of learners as they presented at state and local conferences and shared with their school colleagues. Through the many requirements of the initiative, the teachers grew in their confidence to plan and implement high-quality math lessons embedding technology.

Scholars reported numerous positive aspects of the program. This program met all of the characteristics of effective professional development identified by Bates and Morgan (2018): (1) focus on content, (2) active learning, (3) support for collaboration, (4) models of effective practice, (5) coaching and expert support, (6) feedback and reflection, and (7) sustained duration. One of the teachers, a first-grade teacher MTLA Scholar called the program "*the most beneficial graduate work I've ever done*" (Associated Press, April 24, 2011). She added, "*So much of what we do is* *teaching with technology, but we're actually getting it into the students' hands and letting them show me what they can do with technology*." Another Scholar, a second-grade teacher, said her teaching methods have shifted. She said she now allows students to discuss problems and teach themselves while she supervises and answers questions. The Scholar stated:

> *I've looked more into how I teach math and, instead of teaching the old way of standing in front of the class and talking, I'm doing a whole lot more of walking around my classroom and letting the kids learn* (Associated Press, April 24, 2011).

An outcome of this initiative was the development of the Elementary Mathematics Specialist Endorsement at the university. This collaborative effort between the School of Teacher Education and the Mathematics Department created the first Elementary Mathematics Specialist Endorsement in the state. The program now has impacted many more teachers who have completed the coursework for the endorsement. The program sustains the MTLA work by continuing many of the tasks completed by the scholars. More importantly, the program emphasizes the value of teachers growing their beliefs in affecting student learning in mathematics along with the teachers learning more mathematics content and new instructional strategies, including technology integration.

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