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# TEACHERS' SELF-EFFICACY AND KNOWLEDGE FOR THE INTEGRATION OF TECHNOLOGY IN MATHEMATICS INSTRUCTION AT URBAN SCHOOLS

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*This study examined teachers' technology integration (TI) self-efficacy and technological pedagogical content knowledge (TPACK). We surveyed 80 K-12 mathematics teachers from urban school districts before and after a three-week professional development (PD) program. Results indicated that: a) beliefs about mathematics and mathematics instruction were associated with TI self-efficacy, TPACK dimensions, and instructional technology use, b) TI self-efficacy and TPACK dimensions improved upon PD completion, and c) teachers' perception of technology instruction through PD predicted two dimensions of TPACK. This study has implications for instruction in the use of technology for mathematics teaching provided by teacher preparation and PD programs.*

## Theoretical Framework

It is unequivocal that emerging instructional technologies have the potential to bolster mathematics learning and instruction at urban schools (e.g., International Society for Technology in Education, 2007; National Council of Teachers of Mathematics, 2008). With appropriate use, instructional technology can help teachers enact their teaching-related tasks more effectively, and in turn, facilitate students' learning of mathematics. Given the importance of effective technology integration in mathematics education, we utilized the technological pedagogical content knowledge (TPACK) model—a theoretical framework that addresses teachers' knowledge of effective technology integration in instruction (Mishra & Koehler, 2006)—to investigate the effect that beliefs about mathematics, mathematics teaching, and professional development have on technology integration self-efficacy and knowledge.

### Teachers' Self-efficacy for Technology Integration

Not only do teachers need knowledge of how to incorporate technology into instruction, but they also need to believe that they have the ability to use technology effectively. This belief is known as technology integration (TI) self-efficacy and is associated with technology use in the classroom (e.g., Albion, 1999, c.f. Wang, Ertmer, & Newby, 2004). TI self-efficacy is also closely related to TPACK, a concept that will be further discussed in the next section (Wang et al., 2004).

**Teachers' Technological Pedagogical Content Knowledge**

Technological pedagogical content knowledge (TPACK) is a theoretical framework that addresses teachers' knowledge of effective technology integration in instruction. Developers of TPACK contend that in addition to the importance of teachers' content-specific knowledge and pedagogical knowledge for effective teaching, teachers should also gain knowledge of how to integrate technology in their instruction (Thompson & Mishra, 2007). Through the lens of the TPACK framework, we identified three technology-specific knowledge dimensions as proposed by Mishra and Koehler (2006): technological content knowledge (TCK; the knowledge of how technology can provide new representations of specific content), technological pedagogical knowledge (TPK; the knowledge of how different technologies can be utilized for teaching), and technological pedagogical content knowledge (TPCK; the knowledge necessary for teachers to integrate technology into their teaching of a specific content area). It is important to understand the factors that influence TPACK dimensions because this knowledge can inform PD and teacher education programs about how to best approach curriculum and instruction related to technology use in the classroom (Mishra & Koehler, 2006; Schmidt et al., 2009).

**Effect of Teacher Beliefs on Technology Integration Self-efficacy and Knowledge**

Investigating teachers' educational beliefs about mathematics teaching and learning is important given that mathematics teachers' self-efficacy and epistemic beliefs predict their mathematical knowledge for teaching and their instructional practices (Corkin, Ekmekci, & Papakonstantinou, 2015; Pajares, 1992). Moreover, when considering the influence professional development may have on teachers' integration of technology, it is also essential to examine the effect that teachers' fundamental educational beliefs about teaching and learning have on technology integration, given that teacher beliefs have been identified as barriers to technology use (see Kim, Kim, Lee, Spector, & DeMeester, 2013). For example, a recent study found that less sophisticated epistemic beliefs were associated with lower levels of technology integration in the classroom (Kim et al., 2013). Little research, however, has examined the extent to which fundamental beliefs about teaching and learning relate to the differential utilization of technology in instruction. Moreover, the studies that have examined this relationship have not emphasized domain-specific beliefs (e.g., Kim et al., 2013). Therefore, this study extends extant work by investigating whether key teacher beliefs about mathematics and mathematics instruction, namely, mathematics self-concept, epistemic beliefs about mathematics, and mathematics teaching self-efficacy, play a role in teachers' TI self-efficacy and TPACK dimensions.

### Effect of Professional Development on Technology Integration Self-efficacy and Knowledge

Similar to other social-cognitive types of self-efficacy, research indicates that vicarious learning (modeling) influences TI self-efficacy (Wang et al., 2004). Furthermore, researchers identify modeling as a frequently used strategy to enhance in-service teachers' TPACK (Voogt, Fisser, Roblin, Tondeur, & van Braak, 2012). Thus, this study focuses on whether the quality of a PD program that emphasized modeling of technology use and promoted collaboration would positively influence TI self-efficacy and TPACK.

## Research Questions

The following research questions guided this study:

1. To what extent do teachers' beliefs about mathematics and mathematics instruction relate to their technology integration (TI) self-efficacy, technological pedagogical content knowledge (TPACK), and their self-reported frequency of technology use in mathematics instruction?
2. To what extent do teachers' TI self-efficacy beliefs and TPACK change upon participation in professional development (PD)?
3. What effect does teachers' perceptions of the quality of PD instruction in the use of technology have on teachers' TI self-efficacy and TPACK?

## Method

### Program Description

We surveyed 80 K-12 in-service mathematics teachers from urban school districts in Texas who participated in a three-week rigorous PD program focusing on pedagogical content knowledge and effective technology integration. The teachers volunteered or were selected by school administration to participate in the program. The mathematical content focus was: (a) numbers, operations, and quantitative reasoning; and (b) patterns, relationships, and algebraic reasoning. Integration of technology for effective mathematics instruction focused on three main objectives. Teachers would need to learn to effectively use technology to (1) collaborate and plan for instruction, (2) enhance student learning in numbers and operations, patterns, functions, and algebraic reasoning, and (3) monitor student progress and provide immediate help to students (formative assessment), as well as evaluate student learning (summative assessment).

Technology activities included demonstrations by master teachers (modeling), technology-shares where each participating teacher shared their opinions about an app/software that they found useful, and technology integrated lesson plan assignments where teacher participants received critical and constructive feedback from master teachers. Since the summer PD included teachers from all grade bands at primary and secondary levels, the type of technological devices that teachers modeled and practiced varied. For example, graphing calculators with network ability were used in the high school class but not in the elementary class. The software and apps also varied due to the nature and rigor of mathematics topics covered across classes (from fractions and place value apps in the elementary class to function transformation software in the high school class). However, computers, iPads, interactive white boards, smart phones, GeoGebra, online collaboration and course management tools, presentation tools, and polling apps were modeled and practiced across all grade bands.

**Procedure**

We surveyed teachers several weeks before and after the three-week summer PD program. Survey items were adapted from valid and reliable instruments: 6 items for mathematics self-concept (Marsh, 1990); 8 items for epistemic beliefs in mathematics (Hofer, 2000); 13 items for self-efficacy in teaching mathematics (Enochs, Smith, & Huinker, 2000); 16 items for TI self-efficacy (Wang et al., 2004); and 11 items for technology knowledge (1 TCK, 5 TPK, and 5 TPCK items; Schmidt et al., 2009). In addition to these items, the pre-survey also included items measuring teachers' frequency of use of several technologies for planning, instruction, and assessment (e.g., virtual manipulatives, document cameras). The post survey also included items to assess teacher perceptions about the PD instruction in specific technologies. These perceptions served as a proxy for the program's quality of instruction in the use of technology for planning, instruction, and assessment. Items for frequency of technology use were on a 4-point Likert-scale (0-never to 3-almost always). All other survey items were on a 5-point Likert-scale: 1 (strongly disagree) to 5 (strongly agree) for mathematics epistemic beliefs, mathematics teaching self-efficacy, TI self-efficacy, and TPACK items; 1 (not like me) to 5 (very much like me) for mathematics self-concept items; 0 (not provided) to 4 (excellent) for perceptions of PD instruction in the use of technology. Cronbach's alphas for the scales were: mathematics self-concept (.84), mathematics epistemic beliefs (.67), math-teaching self-efficacy (.83), TI self-efficacy (.94), TPK (.79), and TPCK (.89)

## Participants

In this study, 80 K-12 mathematics teachers representing several urban school districts took the pre- and post- surveys. Ethnic composition of the teachers was 25% White, 40% African American, 21% Hispanic, 13% Asian, and 1% other. There were 63 female teachers (79%) and 17 male teachers (21%). Of all the teachers, 20 attended the elementary class (grades K-3); 19 attended the intermediate class (grades 4-6); 21 attended the middle school class (grades 7-8); and 20 attended the high school class (grades 9-12).

## Findings

Correlation results (Table 1) indicated that teacher beliefs about mathematics and mathematics teaching were associated with TI self-efficacy, TPACK dimensions, and frequency of technology use. Specifically, teachers' personal beliefs about their mathematics ability (mathematics self-concept) was positively associated with their TI self-efficacy ($p < .01$), TPK ($p < .01$), TPCK ($p < .01$), and with their frequency of technology use for planning ($p < .05$) and instruction ($p < .01$). Teachers' beliefs about the certainty of mathematics knowledge—an epistemic belief dimension where the stability of mathematics knowledge is viewed as either certain or evolving—was negatively associated with their frequency of technology use for instruction ($p < .05$) and assessment ($p < .01$). In other words, less sophisticated epistemic beliefs (certainty) were associated with lower frequencies of technology use. Teachers' self-efficacy for mathematics instruction emerged as having statistically significant associations with all technology-related variables, and most of these correlations were stronger compared to the correlations between teacher beliefs about mathematics and technology. Specifically, teachers' self-efficacy for mathematics instruction was positively correlated with TI self-efficacy ($p < .01$), TCK ($p < .01$), TPK ($p < .001$), TPCK ($p < .05$), and with the frequency of technology use for planning ($p < .05$), instruction ($p < .001$), and assessment ($p < .05$). Finally, frequency of technology use was positively associated with both TI self-efficacy and all TPACK dimensions. These correlations ranged from small to moderate ($r = .31$ to $r = 53$).

We conducted paired-samples *t*-tests to investigate whether changes occurred in teachers' self-efficacy and knowledge about the integration of technology (see Table 2). Overall, the changes were statistically significant ($p < .001$) with practically significant effect sizes (ranging from Cohen's $d = 0.58$ to Cohen's $d = 0.75$; see Ferguson, 2009). Specifically, teachers' TI self-efficacy, TCK, TPK, and TPCK increased (0.22, 0.32, 0.53, 0.35, and 0.51 points, respectively).

Table 1. *Means, Standard Deviations, and Pearson Correlations among the Main Variables*

| Variable | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Math Self-Concept | 3.71 | 0.68 | --- | | | | | | | | |
| 2. Math Epistemic Belief: Certain Knowledge | 2.74 | 0.52 | -.07 | --- | | | | | | | |
| 3. Self-efficacy for Math Teaching | 4.04 | 0.46 | .32** | -.02 | --- | | | | | | |
| 4. Technology Integration (TI) Self-efficacy | 3.80 | 0.59 | .37** | -.07 | .38* | --- | | | | | |
| 5. Technology Content Knowledge (TCK) | 3.73 | 0.84 | .20 | -.00 | .30** | .61*** | --- | | | | |
| 6. Technology Pedagogical Knowledge (TPK) | 3.81 | 0.63 | .34** | -.03 | .41*** | .81*** | .69*** | --- | | | |
| 7. Technology Pedagogical Content Knowledge (TPCK) | 3.63 | 0.75 | .31** | -.04 | .28* | .88*** | .62*** | .82*** | --- | | |
| 8. Technology Use: Planning | 1.16 | 0.39 | .29* | -.12 | .25* | .46*** | .39*** | .49*** | .48*** | --- | |
| 9. Technology Use: Instruction | 1.14 | 0.39 | .37** | -.28* | .43*** | .45*** | .43*** | .53*** | .46*** | .78*** | --- |
| 10. Technology Use: Assessment | 0.71 | 0.39 | .19 | -.37** | .23* | .45*** | .31** | .39*** | .44*** | .59*** | .62*** |

$N = 80$; $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 2. *Paired-Samples t-test Results for Change in Teachers' TI Self-efficacy and TPACK*

| | Paired differences (post – pre) | | | | |
|---|---|---|---|---|---|
| Variable | N | Mean gain | SD | *t*-value | Cohen's *d* |
| TI Self-Efficacy | 80 | 0.32 | 0.52 | 5.50*** | 0.61 |
| TCK | 80 | 0.53 | 0.86 | 5.48*** | 0.61 |
| TPK | 80 | 0.35 | 0.60 | 5.20*** | 0.58 |
| TPCK | 80 | 0.51 | 0.68 | 6.72*** | 0.75 |

*Notes.* $^{***}p < .001$.

Table 3 displays the results of four multiple linear regression analyses predicting TI self-efficacy, TCK, TPK, and TPCK at the end of the three-week PD. Teachers' TI self-efficacy and TPACK dimensions at the onset of PD were entered as control variables in order to understand the extent to which perceptions about the quality of PD technology instruction predicted TI self-efficacy and TPACK dimensions at the end of PD beyond teachers' initial levels of TI self-efficacy and TPACK. The models with TPK and TPCK as the outcome variables were statistically significant ($F(2, 77) = 17.92$, $p < .001$, $R^2 = 32\%$; $F(2, 77) = 17.53$, $p < .001$, $R^2 = 31\%$, respectively. Results indicated that more positive perceptions of PD quality were statistically significantly associated with TPK ($\beta = .25$, $p < .05$) and TPCK ($\beta = .19$, $p < .05$) after controlling for initial TPK and TPCK levels.

Table 3.

*Summary of Multiple Linear Regression Analyses Predicting Technology Beliefs and Knowledge*

| Variable | Post-TI S.E. | Post-TCK | Post-TPK | Post-TPCK |
|---|---|---|---|---|
| | β | β | β | β |
| *Control Variables* | | | | |
| Pre-TI Self-Efficacy | .59*** | --- | --- | --- |
| Pre-TCK | --- | .40*** | --- | --- |
| Pre-TPK | --- | --- | .48*** | --- |
| Pre-TPCK | --- | --- | --- | .51*** |
| *Main Predictor* | | | | |
| Perceptions of PD Tech Instruction | .18 | .17 | .25* | .19* |
| $R^2$ | .40*** | .20*** | .32*** | .31*** |

*Notes.* $N = 80$; $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. "---": variable not included in analysis.

## Discussion and Conclusions

The study expands our knowledge about the types of teacher educational beliefs that may impede the integration of technology in mathematics instruction. One significant and perhaps novel finding is that mathematics teaching self-efficacy is moderately associated with numerous indicators of technology use in the classroom (TI self-efficacy, TPACK domains, and self-reported use of technology). Current findings suggest that for teachers to feel confident in integrating technology, they must also feel self-efficacious about mathematics teaching in general. A second significant finding is that teachers' perceptions of PD instruction in technology integration are positively associated with TPK and TPCK at the end of the PD program. This finding is consistent with research indicating that modeling technology integration and enacting technology-based lessons through collaboration in teacher education programs are effective means of developing TPACK (see Voogt et al., 2012). In closing, these findings are important because they may inform teacher preparation and PD programs about the importance of incorporating technological instruction to promote teachers' use of technology in mathematics teaching. These findings also suggest that PD instructors keenly assess teachers' fundamental beliefs about mathematics and mathematics instruction, as these beliefs may inhibit teachers from incorporating technology in their classrooms.

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