# THE EFFECTS OF A TECHNOLOGY COURSE WITH COLLABORATIVE DESIGN ON PROSPECTIVE TEACHERS' KNOWLEDGE AND BELIEFS

Jon D. Davis
Western Michigan University
jon.davis@wmich.edu

*This study investigates the effects of a technology methods course containing a unique collaborative design experience on prospective elementary and secondary mathematics teachers' technological beliefs, computer algebra system (CAS) beliefs, and technological pedagogical content knowledge (TPACK). Overall gain scores on all three instruments were statistically significant. Moreover, gender and level (elementary vs. secondary) were statistically significant predictors of TPACK gain scores. However, the influence of level on TPACK gain score was different for female prospective teachers (PTs) than male PTs. Even in the case of low gain scores PTs displayed beliefs that were aligned with productive uses of technology in the classroom. PTs showed greater gains on knowledge subdomains associated with technological knowledge than on technology free subdomains (e.g., pedagogical content knowledge).*

Keywords: technology, teacher beliefs, teacher knowledge

Technology plays an increasingly pervasive role in our everyday lives and that influence extends into school classrooms. Yet research suggests that technology is often used to support current educational practices instead of as a catalyst for change (e.g., Cuban, Kirkpatrick, & Peck, 2001). The mathematics education community has created an extensive body of research that has recognized the important role that both knowledge (e.g., Meagher, Özgün-Koca, & Edwards, 2011) and beliefs (e.g., Kim et al., 2013) play in shaping teachers' decisions around the use of technology in school classrooms. One particularly popular conceptual framework for thinking about the knowledge that teachers need to possess in these classrooms is technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006). A variety of approaches have been used to promote TPACK among practicing and prospective teachers. One of the more popular approaches involves collaboration in the design of technology-infused lessons (e.g., Koehler & Mishra, 2005). This study examines the effect of a technology methods course containing a unique collaborative design environment on prospective elementary teachers' (PSETs') and prospective secondary mathematics teachers' (PSTs') beliefs about technology in general, beliefs about computer algebra systems (CAS), and their TPACK knowledge.

## Background

TPACK is one of the most frequently used frameworks to conceptualize and research the knowledge that teachers who teach successfully with technology need to possess. A variety of interventions have been found to positively influence the TPACK of prospective teachers such as technology rich field experiences (Meagher, Özgün-Koca, & Edwards, 2011), collaborative design experiences (e.g., Agyei & Voogt, 2012), and engaging students in solving mathematics problems with technology (Meagher et al.). Wang, Schmidt-Crawford, and Yin (2018) reviewed 88 empirical studies and found that modeling of the integration of technological, pedagogical, and content knowledge in university courses and by practicing teachers was an effective way of increasing the TPACK of prospective teachers (PTs). Their synthesis also suggests that gaining experience teaching with technology, engaging in peer mentoring, and learning technological knowledge are important in developing PTs' integrated knowledge domains such as technological content knowledge (TCK).

In: Sacristán, A.I., Cortés-Zavala, J.C. & Ruiz-Arias, P.M. (Eds.). (2020). *Mathematics Education Across Cultures: Proceedings of the 42nd Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*, Mexico. Cinvestav / AMIUTEM / PME-NA. https:/doi.org/10.51272/pmena.42.2020

An extensive collection of research has highlighted the connections between beliefs and teaching practices (e.g, Kim et al., 2013) and numerous studies have investigated teachers' beliefs with regard to technology. One way to conceptualize teacher beliefs regarding technology is what I refer to as the *role of technology in mathematics classrooms* which consists of a continuum with *doing mathematics* on one end and *learning mathematics* on the other end. Beliefs aligned with doing mathematics include the mastery principle (Fleener, 1995), "old school" (Erens & Eichler, 2015), and the restriction of CAS black box techniques (Doerr & Zangor, 2000). Individuals professing a learning mathematics position do not believe that students must learn fundamental ideas before technology; technology can be used as a tool to learn mathematical ideas (Lagrange, 1999). Proponents of a doing mathematics position argue that students should not use technology until they have learned the concepts or procedures that the technology can perform. An assumption hidden within this position, which is in contrast to the learning mathematics position is that students learn mathematics solely through paper-and-pencil work, not with technology. A belief that is aligned with the doing mathematics position is that even if technology is only allowed until students have acquired the paper-and-pencil skills they can still lose proficiency with these skills if technology is used too frequently, often described as technology becoming a "crutch" (e.g., Schmidt, 1999).

Beliefs are often connected to other personal characteristics. Tharp, Fitzsimmons, and Ayers (1997) found that practicing secondary teachers used technology more extensively in the classroom if they possessed less rule-based perspectives of mathematics. Teo and colleagues (2008) found that constructivist teaching beliefs of PTs were positively correlated with both constructivist and traditional use of technology while traditional teaching beliefs were negatively correlated with a constructivist use of technology. There is also an extensive body of research highlighting connections between gender and technology (e.g., Sanders, 2006).

Previous research has uncovered connections between TPACK and gender. For example, Bulut and Işiksal-Bostan (2019) found that male PSETs had significantly higher scores than female PSETs in TPK, TK, and TPACK. The relationship between TPACK and beliefs is mixed. For instance, Niess (2013) found that teachers' TPACK levels were occasionally connected to their beliefs. Similarly, Smith, Kim, and Mcintyre (2016) investigated the TPACK and beliefs held by four prospective middle grades teachers. Two of the teachers appeared to show relationships between beliefs and TPACK, where more student-centered views of mathematics teaching and learning were aligned with higher levels of TPACK for one teacher. More teacher-centered views of mathematics teaching and learning were aligned with lower levels of TPACK for another teacher. The results for the other two teachers were less clear.

This study builds on this extensive collection of research to investigate the effects of a technology methods course involving both PSETs and PSTs on their beliefs and TPACK. The technology methods course at the center of this study contains components that have been found to have significant impacts on the TPACK of PTs (Wang et al., 2018) as well as a previously uninvestigated collaborative design environment. This study was designed to answer three research questions.

1. In what ways does a technology methods course involving a collaborative design experience influence PTs' technological beliefs and CAS beliefs?
2. In what ways does a technology methods course involving a collaborative design experience influence PTs' TPACK and related knowledge subdomains?
3. Does a technology methods course involving a collaborative design experience differentially impact PTs' beliefs or TPACK knowledge depending on the gender or level (secondary vs. elementary) of participants?

# Methodology

## Frameworks

The TPACK framework (Mishra & Koehler, 2006) was used to understand the knowledge gained by PTs as a result of the activities comprising the technology methods course. This framework highlights the separate and interconnected nature of three different knowledge areas. By separate I mean that knowledge exists that is solely, technological, pedagogical, and content in nature that teachers must possess in using technology successfully in the classroom. For instance, purely technological knowledge comes into play when students "break" a pre-constructed technological document and the teacher must deploy his/her/their technological knowledge to diagnose and repair the problem. By integrated I mean that in addition to TPACK which involves the complex interplay of technological, pedagogical, and content knowledge there exist three other integrated knowledge types: pedagogical content knowledge (PCK); technological content knowledge (TCK); and technological pedagogical knowledge (TPK).

The learning by design framework (Koehler & Mishra, 2005) guided the construction of collaborative design experiences that PTs experienced in the technology methods course as the center of this study. The framework involves learning-by-doing and extended design work on authentic problems. Specifically, learning-by-doing involves two components: construction of lessons involving technology and the teaching of those lessons in middle school and high school classrooms. Authentic problems are those that teachers working in schools frequently encounter such as how to incorporate technology into a textbook lesson that does not currently contain technology or how to develop technology-rich activities that help students to develop conceptual understanding of important mathematical ideas. The course instructor often acts as a facilitator or problem-solving expert.

## Context

The study took place in a large university in the midwestern U.S. that is known for its teacher preparation program. In the past, the technology methods course taught in the mathematics department, only enrolled PSTs, but the development of an Elementary Education Mathematics Major with a certification across grades K-8 necessitated the creation of another course focusing on technology use at the middle school level (grades 6-8) for these individuals. Since the development of the middle school mathematics technology course both courses have been taught at the same time and place and by the same instructor. The class met for two 100-minute sessions a week for 12 weeks. The course where the data for this study were collected was taught during the Spring 2019 semester. A total of five prospective elementary teachers (PSETs) and four PSTs were enrolled in the jointly-held course and chose to participate in the study.

PTs enrolled in both classes developed lesson plans and student activity sheets. The lesson plan involved components such as lesson objectives, places where students might struggle, how student struggles would be addressed, answers to lesson questions, and estimated time required for students to complete various lesson components. The student activity sheet involved a warm-up (if the PT chose to include one), activities and questions students were to complete, and oftentimes an exit ticket. The focus of the lesson was on conceptual understanding, the use of technology to help students learn the objectives of the lesson, the use of one or more high cognitive demand tasks (Stein & Smith, 1998), and the inclusion of at least one class discussion. All lessons taught in area classrooms involved middle school mathematics. The use of teaching experience with lessons involving technology has been found to positively affect prospective teachers' TPACK knowledge (Wang et al., 2018).

The class involved two different types of group lesson planning structures: brainstorming and refinement. Brainstorming involved the development of general ideas about a lesson without the creation of specific lesson elements. Refinement involved the presentation and critique of a student activity sheet. Brainstorming occurred if the PT was struggling to develop a lesson plan and student activity sheet while refinement was used if the PT had already completed a lesson plan and student activity sheet. PTs engaged in the development of lesson plans and student activity sheets individually, as part of a large group consisting of the entire class, and working with the instructor of the course. All of the PTs wrote a paper detailing the planning, enactment, and reflection regarding their lesson.

In addition to the presentations and brainstorming sessions, the PTs engaged in the following activities in the technology methods course: solving mathematics problems using technology; completing journal entries designed to make their beliefs regarding technology transparent to them; reading mathematics education articles involving technology and reacting to them; exploring the symbolic manipulation capabilities of CAS, the completion of a project involving the solution of an infinite class of optimization problems using graphical, tabular, and CAS capabilities; and considering how technology can be implemented in mathematics textbook lessons that do not currently use technology. Each PT created a lesson plan and student activity sheet which were either presented to the classroom for critique and refinement or began as brainstorming sessions for a total of nine lessons involving technology.

## Instruments

A technology beliefs survey was administered to PTs on the first day of class and again on the last day of class. The beliefs survey was adapted from Schmidt (1999) in the following ways. First, the words calculator or calculators were replaced with technology. Second, items involving practicing teachers that referenced components of their work that were not applicable to prospective teachers (e.g., perspective of parents of their students) were removed. A frequently used TPACK questionnaire (Schmidt et al., 2009) consisting of 58 items measuring seven different knowledge domains was administered during the first day of class and again during the last day of class.

This questionnaire contains items in four different content areas: mathematics; literacy; science; and social studies. In addition to measuring TPACK (five items), the questionnaire also measures technological knowledge (TK) (seven items), content knowledge (CK) (three items), pedagogical knowledge (PK) (seven items), pedagogical content knowledge (PCK) (one item), technological content knowledge (TCK) (one item), and technological pedagogical knowledge (TPK) (four items). This TPACK questionnaire was used with the group of PSETs as this was the population for which the instrument was developed.

The questionnaire was adapted for PSTs (resulting in 44 items) by removing the CK, TCK, and PCK items related to literacy, science, and social studies and replacing them with similar items related to the students' minor degrees (e.g., history). Given the work that the PTs completed with CAS described earlier, I also administered a CAS beliefs survey (Lavicza, 2010) on the first day and last day of class to determine whether their beliefs regarding this powerful technology had changed as a result of the activities in the technology methods course. This survey, consisting of 20 items, was adapted as the original was intended for faculty teaching mathematics at the university level. For instance, the word *mathematicians* in the item, CAS enables mathematicians to work on problems more efficiently, was replaced with *students*. The technology beliefs survey, CAS beliefs survey, and TPACK questionnaire consist of Likert scale items that range from strongly disagree to strongly agree. None of the PTs were enrolled in another course that involved the use of technology during the Spring 2019 semester, but all were taking either foundational education courses or courses involving pedagogical components. Thus, there is a potential that the gains seen on the instruments with regard to pedagogy could be a result of these other courses. Three out of four of the PSTs were enrolled in mathematics content courses during Spring 2019, but this was a modern algebra course that did not highlight the connections between its content and school mathematics.

## Analysis

I assigned a numerical score for each of the Likert scale items (strongly disagree – 1, disagree – 2, neutral – 3, agree – 4, strongly agree – 5). For each item of the technology belief survey and CAS beliefs survey, the differences between the first and last administration were calculated and the sum was found for each PT. Items that were negatively worded were reverse scored. The mean of the totals across the group of PSETs and the group of PSTs were found. All of the collected data were examined for trends. As there were different numbers of questions for the knowledge subdomains in the TPACK questionnaire, each PT's difference was divided by the number of questions that contributed to that difference for reporting purposes. The mean of these values was reported for each PT as an average gain value that enables comparisons to be made across different knowledge subdomains. The assumptions for the statistical tests (e.g., normality) were met and an alpha level of .05 was used for all statistical tests. The paired samples *t*-test was used to test for statistical significance for gain scores on each of the three instruments. Effect sizes were found by converting a *t*-value into an *r*-value (Rosnow & Rosenthal, 2005). A factorial ANOVA test was run on the gain scores for technological beliefs, CAS beliefs, and the TPACK questionnaire with gender and level (elementary and secondary) as independent factors.

## Results

Overall, PTs scored higher on the second administration ($M = 130.11$, $SD = 12.424$) than the first administration ($M = 110.22$, $SD = 4.324$) on the technological beliefs survey and this result was statistically significant, $t(8) = -4.850$, $p = .001$, $r = .86$. In the factorial analysis, the independent factors of gender and level as well as the interaction were statistically non-significant. The changes in technological beliefs for PSETs and PSTs are shown in Table 1. The beliefs score changes for PSTs were greater than the score changes for PSETs. Three questions were common across both groups in terms of the greatest change between administrations of the technological beliefs survey. The first of these involved the belief that technology can damage students' paper-and-pencil skills and become a "crutch." A total of four out of nine of the PTs started out agreeing or strongly agreeing with this statement and shifted to disagreeing with this statement. The remaining five teachers either disagreed with the statement across both administrations of the survey or moved from disagree to strongly disagree. The second of these questions stated that students who use technology in high school mathematics classes learn mathematics better than those who do not use technology. Six out of nine of the PTs moved from disagree/neutral with regard to this statement to agreeing with it. The last statement involved prospective teachers' lack of confidence to teach mathematics involving technology. Six out of nine PTs agreed with this statement at the start of the class, but by the end of class they all disagreed with the statement.

Overall, PTs scored higher on the second administration ($M = 69.89$, $SD = 8.42$) than the first administration ($M = 57.78$, $SD = 6.14$) on the CAS beliefs survey and this result was statistically significant, $t(8) = -3.210$, $p = .012$, $r = .75$. In the factorial analysis, the independent factors of gender and level as well as the interaction were statistically non-significant. The changes in CAS beliefs for PSETs and PSTs are shown in Table 1. There were several low change scores in the table. For instance, Logan had no change on the technological belief survey, Liam had a CAS belief change of only two, and Madison had a change of -1 on the CAS belief survey. All of these PSETs possessed a number of initial beliefs that were aligned with an environment where technology is seen as a valuable tool to assist in the teaching of mathematics. For instance, Logan professed initial beliefs on 19 out of the 39 technological beliefs questions that were aligned with practices presented in the class. Across all PTs, two questions had highest gains from first to last administration: CAS promotes students' conceptual understanding; and CAS can be used to develop more engaging lessons.

**Table 1: Changes in Beliefs for PSETs and PSTs**

| Prospective Teacher[a] | Technological Belief Change | CAS Belief Change |
|---|---|---|
| | PSETs | |
| Liam | 26 | 2 |
| Sophia | 20 | 20 |
| Amelia | 13 | 6 |
| Logan | 0 | 15 |
| Madison | 14 | -1 |
| **Mean** | **14.60** | **8.4** |
| | PSTs | |
| Noah | 12 | 6 |
| Emma | 40 | 23 |
| Olivia | 35 | 33 |
| Mason | 19 | 5 |
| **Mean** | **26.50** | **16.8** |

[a] All names are pseudonyms.

Overall, PTs scored higher on the second administration (*M* = 118.78, *SD* = 7.19) than the first administration (*M* = 102.44, *SD* = 12.78) of the TPACK questionnaire and this result was statistically significant, *t*(8) = –4.599, *p* = .002, *r* = .85. There was a significant main effect of gender on the TPACK gain score *F* (1, 5) = 14.12, *p* = .013, *,ω-2.=.15*. The main effect of level on the TPACK gain score was statistically significant *F* (1, 5) = 7.73, *p* = .039, *,ω-2.=.08*. Additionally, there was a statistically significant interaction between gender and group on TPACK gain score *F* (1, 5) = 59.904, *p* = .001, *,ω-2.=.67*. In other words, the influence of level on TPACK gain scores is different for female PTs than male PTs. Specifically, male PSETs had higher TPACK gain scores (*M* = 18.5, SD = 3.54) than females PSETs (*M* = 9.67, SD = 2.08). Female PSTs had higher TPACK gain scores (*M* = 33.00, SD = 2.83) than male PSTs (*M* = 7.50, SD = 4.95).

The knowledge gains by content subdomain for PSET and PST are shown in Table 2. For both groups the technology methods course appeared to have only a moderate influence on their content knowledge, technological knowledge, pedagogical knowledge, and pedagogical content knowledge. Both groups experienced the greatest knowledge gains in the TCK and TPACK areas. PSTs also experienced larger gains in the area of TPK.

Amelia experienced a loss of four in the area of TPK on the questionnaire. This occurred because on three of the five statements she moved from strongly agree to agree resulting in a drop of negative three. On the fourth statement in this area she had no change from agree while on the last statement she moved downward from agree to unsure. Mason also had a sum for a content subdomain (TK) that was negative. On four of the seven questions comprising this area, he had no change from agree or strongly agree on the initial and final questionnaire. On the three other questions, he moved from agree or strongly agree to unsure. Noah also had a sum of negative one in the knowledge subdomain of TCK that included one question. On this question, he moved from strongly agree to agree. In sum, despite decreases in change scores for some of the PTs that resulted in overall decreases the final rating on the majority of these statements was still in the agree category.

**Table 2: Changes in Knowledge for PSETs and PSTs**

| Prospective Teacher | TK | CK | PK | PCK | TCK | TPK | TPACK | Total |
|---|---|---|---|---|---|---|---|---|
| | | | | PSETs | | | | |
| Liam | 1 | 0 | 4 | 1 | 2 | 2 | 6 | 16 |
| Sophia | 0 | 1 | 3 | 0 | 2 | 3 | 3 | 12 |
| Amelia | 4 | 0 | 2 | 0 | 2 | -4 | 4 | 8 |
| Logan | 1 | 1 | 6 | 0 | 0 | 5 | 8 | 21 |
| Madison | 1 | 1 | 2 | 1 | 0 | 3 | 1 | 9 |
| **Average Gain** | 0.2 | 0.2 | 0.49 | 0.2 | **1.20** | 0.36 | **0.88** | 13.20 |
| | | | | PSTs | | | | |
| Noah | 2 | 0 | 1 | 0 | -1 | 2 | 0 | 4 |
| Emma | 7 | 1 | 12 | 2 | 1 | 5 | 7 | 35 |
| Olivia | 9 | 3 | 3 | 1 | 2 | 6 | 7 | 31 |
| Mason | -4 | 0 | 1 | 0 | 2 | 6 | 6 | 11 |
| **Average Gain** | 0.61 | 0.33 | 0.61 | 0.75 | **1.00** | **1.19** | **1.00** | 20.25 |

## Discussion

As a group, across all three instruments, PTs performed statistically significantly better on the second administration than the first administration. Thus, the collection of activities in the technology methods course appeared to positively influence PTs' beliefs and their TPACK. In general, where PTs displayed smaller changes in beliefs, their initial beliefs were already aligned with environments where technology was seen as an important tool in learning mathematics thus they had less room to change. This suggests that simply experiencing activities involving the use of technology to learn mathematics as all of the PTs did in previous courses can promote positive beliefs involving technology.

The PTs demonstrated less growth in CK, PK, and PCK as a result of the technology methods course than they did in the areas of TCK, TPK, and TPACK. This suggests that while topics regarding general pedagogical knowledge, content knowledge, and pedagogical content knowledge emerged during design work, teachers may not have perceived the work as occurring in these domains as the lessons were centered around the use of technology. That is, the PTs might have primarily seen the design work as involving technology. Indeed, on the technological belief survey one of the items of greatest change was their confidence in developing technologically based lessons. This result aligns with the work of Koehler and Mishra (2005) in which their collaborative learning environment resulted in greater connections among technology, pedagogy, and content. The differential gains on TK between PSETs and PSTs might have been a result of the particular lessons the groups developed. PSETs tended to create lessons involving technological applications that were already constructed while PSTs' lessons required them to learn and deploy more technological knowledge.

The PTs had limited work with CAS during the methods course as they used it to learn mathematics at the beginning of the course and solve optimization problems at the end of the course; none of the PTs created a lesson involving CAS. Nonetheless, they made statistically significant gains on this survey. This may have been due to a spillover effect involving the extensive design work in technology. Importantly, the technology methods course and its limited use of CAS resulted in a shift to envisioning the CAS as a tool to develop students' conceptual understandings much like the teachers Lagrange (1999) investigated. This is an interesting finding as PTs did not specifically use CAS in activities focused on conceptual understanding. This finding suggests that the collaborative design experiences and their focus on conceptual understanding affected PTs' beliefs in a different type of technology than where this work occurred.

As mentioned earlier, there were a few negative gain scores sprinkled throughout the results even though many of the PTs with these values were still agreeing with beliefs that were aligned with the use of technology to promote mathematics understandings and greater TPACK knowledge. These losses might have reflected a correcting of overly optimistic beliefs or knowledge as a result of deep engagements with technology during the collaborative design process.

Despite previous findings with regard to gender and technology (Sanders, 2006) this study found no relationship between gender and technological beliefs or gender and CAS beliefs. However, gender, level, and the interaction between gender and level were significant predictors of TPACK gain scores. Female PSETs had lower initial scores than male PSETs on the TPACK questionnaire overall. Thus, male PSET gain scores might have been lower than females because there was less room to grow. Female PSTs had the lowest initial TPACK scores among all both groups, about 20 points lower than female PSETs giving them more space to grow. PSETs had experienced more mathematics courses that incorporated technology and one more mathematics methods course than PSTs. These factors might have translated into higher initial TPACK scores. The higher TPACK scores among male students overall is similar to the findings of Bulut and Işiksal-Bostan (2019).

In sum, these findings illustrate the effectiveness of a technology methods course on PTs' beliefs and TPACK knowledge. The study is limited by its reliance on self-report data and the small sample size. In the future, I intend to examine other data (e.g., PT classroom enacted lessons involving technology) to move beyond self-report data in understanding the effect of the course on PTs' TPACK. Moreover, the study focused on the effect of the technology methods course as a whole on PTs' beliefs and knowledge and while the collaborative context was described in detail, the effects of this unique factor on PTs were not isolated. My future research intends to more carefully investigate the effects of this unique activity on PTs' beliefs and knowledge. The omnipresence of technology in today's classrooms necessitates that teachers be prepared to use it in ways that draw on its unique affordances and its potential to change mathematics instead of in ways that support traditional instruction (Cuban et al., 2001).

## References

Agyei, D. D., & Voogt, J. (2012). Developing technological pedagogical content knowledge in pre-service mathematics teachers through collaborative design. *Australasian Journal of Educational Technology, 28*(4), 547-564.

Bulut, A., & Işiksal-Bostan, M. (2019). Perceptions of pre-service elementary mathematics teachers on their technological pedagogical content knowledge (TPACK) regarding geometry. *Journal of Computers in Mathematics and Science Teaching, 38*(2), 153-176.

Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal, 38*(4), 813-834.

Doerr, H. M., & Zangor, R. (2000). Creating meaning for and with the graphing calculator. *Educational Studies in Mathematics, 41*, 143-163.

Erens, R., & Eichler, A. (2015). The use of technology in calculus classrooms – beliefs of high school teachers. In C. Bernack-Schüler, R. Erens, T. Leuders, & A. Eichler (Eds.), *Views and beliefs in mathematics education. Results of the 19th MAVI conference* (pp. 133-144). Germany: Springer. DOI: 10.1007/978-3-658-09614-4_11

Fleener, M. J. (1995). The relationship between experience and philosophical orientation: A comparison of preservice and practicing teachers' beliefs about calculators. *Journal of Computers in Mathematics and Science Teaching, 14*, 359-376.

Kim, C., Kim, M. K., Lee, C., Spector, M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education, 29*, 76-85.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131-152.

Lagrange, J. (1999). Techniques and concepts in pre-calculus using CAS: A two-year classroom experiment with the TI-92. *International Journal of Computer Algebra in Mathematics Education, 6*(2), 143-165.

Lavicza, Z. (2010). Integrating technology into mathematics teaching at the university level. *ZDM Mathematics Education, 42*, 105-119.

Meagher, M., Özgün-Koca, S. A., & Edwards, M. T. (2011). Preservice teachers' experiences with advanced digital technologies: The interplay between technology in a preservice classroom and in field placements. *Contemporary Issues in Technology and Teacher Education, 11*(3), 243-270.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A new framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

Niess, M. L. (2013). Central component descriptors for levels of technological pedagogical content knowledge. *Journal of Educational Computing Research, 48*(2), 173-198.

Rosnow, R. L., & Rosenthal, R. (2005). *Beginning behavioural research: a conceptual primer* (5th ed.). Englewood Cliffs, NJ: Pearson/Prentice Hall.

Sanders, J. (2006). Gender and technology. In C. Skelton, B. Francis, & Smulyan, L. (Eds.), *The SAGE handbook of gender and education* (pp. 307-321). London: SAGE Publications.

Schmidt, M. E. (1999). Middle grade teachers' beliefs about calculator use: Pre-project and two years later. *Focus on Learning Problems in Mathematics, 21*(1), 18-34.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK) the development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education, 42*(2), 123-149.

Smith, R. C., Kim, S., & McIntyre, L. (2016). Relationships between prospective middle grades mathematics teachers' beliefs and TPACK. *Canadian Journal of Science, Mathematics and Technology Education, 16*(4), 359-373.

Stein, M. K., & Smith, M. S. (1998). Mathematical tasks as a framework for reflection: From research to practice. *Mathematics Teaching in the Middle School, 3*(4), 268-275.

Teo, T., Chai, C. S., Hung, D., & Lee, C. B. (2008). Beliefs about teaching and technology among pre-service teachers. *Asia-Pacific Journal of Teacher Education, 36*(2), 163-174.

Tharp, M. L., Fitzsimmons, J. A., & Ayers, R. L. B. (1997). Negotiating a technological shift: Teacher perception of the implementation of graphing calculators. *The Journal of Computers in Mathematics and Science, 16* 551-575.

Wang, W., Schmidt-Crawford, D., & Jin, Y. (2018). Preservice teachers' TPACK development: A review of literature. *Journal of Digital Learning in Teacher Education, 34*(4), 234-258.