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# Preparing Elementary Preservice Teachers to Integrate Technology: Examining the Effects of a New Science Course Sequence with Technology Infusion

Diana Fenton
*College of St. Benedict/St. John's University*

**ABSTRACT**

Elementary teacher preparation programs often separate content and technology courses. This study examined the impact of changing the required science content courses for elementary preservice teachers in a small liberal arts setting. Following the new science course, students participated in a field experience as part of an elementary science pedagogy course that required using technology when delivering content lessons. We compared the students' perceived technological, pedagogical, and content knowledge (TPACK) and confidence teaching with the technology between the two groups. Data was collected using the TPACK survey at the end of their teacher preparation program. The analysis showed a significant difference in students' perceived TPACK between a discipline-specific science course and a multidisciplinary course, except in one dimension, pedagogical knowledge (PK). Overall, candidate confidence in combining content and technology in teaching a classroom lesson was higher with the multidisciplinary course. However, students could not effectively describe specific episodes that indicate high-level, inquiry-based teaching but did describe overall knowledge of technological pedagogical knowledge.

*Keywords:* infused, pedagogy, preservice teachers, TPACK

## Introduction

Preparing elementary preservice teachers to teach science using technology is a complex process. To be effective, candidates need knowledge of essential science concepts and skills, effective pedagogy, and digital tools and resources. Because these domains of expertise do not exist in separate silos, future teachers need opportunities to plan instruction that allows them to consider the most effective pedagogy and technology for teaching specific science concepts and skills.

Teacher preparation programs must consider how best to prepare their teacher candidates with the technological, pedagogical, and content knowledge (TPACK) needed to teach all disciplines, including science. This paper describes our approach to preparing elementary preservice teachers to make meaningful use of technology when teaching science content.

### Science Content Preparation

Preparing elementary preservice teachers to teach all of the disciplines of science is complicated. Some colleges introduce future teachers to science content in multidisciplinary courses, but most depend on discipline-specific classes open to students across all majors offered at the college or university. This approach affords an extended amount of time to learn the concepts and skills associated with a single discipline (e.g., biology, chemistry, physics, etc.). Research, however, suggests that elementary preservice teachers continue to lack confidence in the sciences with this approach because the modeling of effective pedagogical practices is limited (Bergman & Morphew, 2015). Without proper modeling and relevant inquiry-based learning, elementary preservice teachers' attitudes towards and confidence in science may ultimately play a role in the amount of time they will devote to science instruction in their future classrooms (Bursal & Paznokas, 2006; National Research Council, 2007). Finding the best approach to prepare elementary preservice teachers with the knowledge and confidence to teach science is one area still being explored by many teacher preparation programs. One trending theme is the creation of multidisciplinary courses. Multidisciplinary science content courses explicitly designed for prospective elementary teachers and taught by trained pedagogues may address some of the identified concerns (Avery & Meyer, 2012; Bergmann & Morphew, 2015; Kirst & Flood, 2017; Knaggs & Sondergeld, 2015; Long 2019; Menon & Sadler, 2016).

## Technology Preparation

In addition to ensuring elementary preservice teachers possess adequate science content knowledge, teacher preparation programs must also identify effective ways to help future teachers make meaningful pedagogical use of technology. Various factors, including time, resources, knowledge, and beliefs, impact teachers' pedagogical use of technology (Ottenbreit-Leftwich et al., 2010). The most significant predictor of technology use for preservice teachers is their self-efficacy with technology and beliefs in the value of technology in the classroom (Anderson et al., 2011). Therefore, teacher preparation programs must consider the impact of candidates' technology beliefs and knowledge when designing learning experiences.

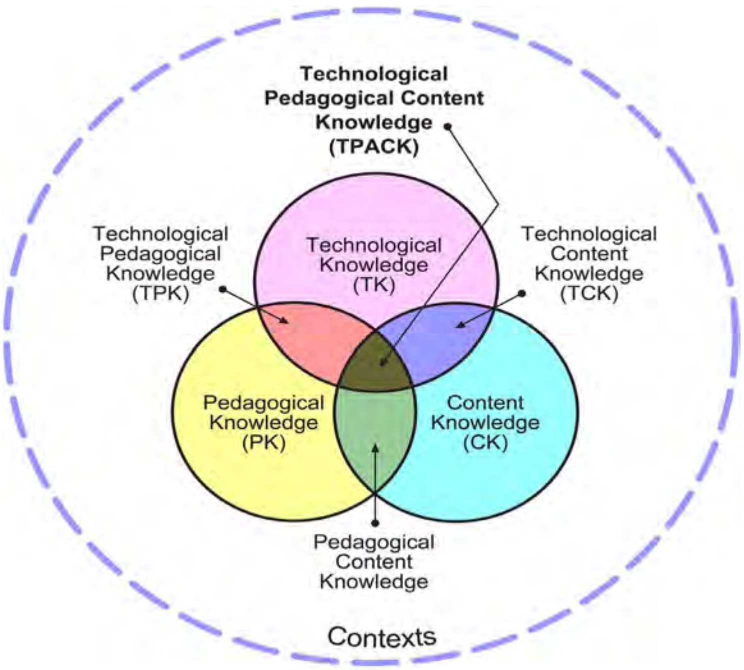
## Theoretical Framework

This study and the design of our elementary-level science and pedagogy courses are grounded in the Technological, Pedagogical, and Content Knowledge (TPACK) framework (Kohler & Mishra, 2009; Mishra & Koehler, 2006), see Figure 1. The framework creators argue that technology, pedagogy, and content are interrelated; and that teacher preparation programs must help candidates develop the knowledge and skills needed across all three domains. While this framework is applicable across academic disciplines, we focus specifically on science education.

Preparing elementary preservice teachers who understand the complex interplay of science content, technology, and pedagogy is essential but also a significant challenge for teacher preparation programs. Focusing on any of these components (i.e., science content, pedagogy, or technology) in isolation reveals the breadth and depth of knowledge and skills future elementary science teachers will need. For example, science content knowledge (CK) requires expertise in multiple disciplines, each focused on its own set of disciplinary concepts, methods of inquiry, and discursive practices. Pedagogical knowledge (PK), equally complex, requires an understanding of the subject matter, purposes and values of education, learning and learners, curriculum and planning, classroom management, assessment, resources, and context (Hashweh, 2018; Kurt, 2018; Mishra & Koehler, 2006). Finally, technology knowledge (TK) requires knowledge of and the ability to use a variety of technologies, applications, and corresponding resources (Kurt, 2018; Mishra & Koehler, 2006).

**Figure 1**

*Graphic Representation of Technological, Pedagogical, Content Knowledge (TPACK) Adapted from http://tpack.org/ Website and Used with Permission*




Elementary teachers do not, of course, apply the knowledge and skills associated with these domains in isolation. Shulman (1986) developed a framework that enables an examination of the intersection of content and pedagogy. According to Shulman, teachers' pedagogical content knowledge (PCK) includes "an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" and "knowledge of the strategies most fruitful in reorganizing the understanding of learners" (p. 9-10). In other words, effective teachers must understand the central concepts and skills of their discipline and be able to make that content accessible to their learners. Mishra and Koehler (2006) extended Shulman's framework to include technology. They contend that in addition to possessing knowledge of content and pedagogy, teachers need to be prepared to make effective pedagogical use of technology when teaching their content. Thus, to be effective, teachers need technological content knowledge (TCK), which includes understanding the role of technology in their discipline (e.g., biology, mathematics, history); technological pedagogical knowledge (TPK), or the ability to teach with and about technology; and technological pedagogical content knowledge, the ability to integrate the three domains of technological knowledge, pedagogical knowledge, and content knowledge (TPACK).

The TPACK framework is a valuable tool for examining teacher-preparation programs and has led to significant recommendations for improving prospective teachers' pedagogical uses of technology (DeCoito & Richardson, 2018). This work guided both the design of this study and the preparation of our elementary preservice teachers to teach science with technology.

## Designing a New Course Sequence

To improve elementary preservice teachers' science content knowledge, pedagogical skills, and technology preparation, the elementary science pedagogy course was revised, and a new multidisciplinary science content course was developed. The new science content course, created specifically for future elementary teachers, replaced two previously required discipline-specific introductory science courses (e.g., biology, chemistry, physics, etc.). The new course was designed specifically to ensure elementary candidates 1) develop the science content knowledge needed to teach required academic standards, 2) experience effective pedagogical practices, 3) learn to make meaningful use of technology in their lessons, and 4) develop confidence in and enthusiasm for teaching science. The instructor for the multidisciplinary science course has expertise in both pedagogy and content with advanced degrees in both areas.

The multidisciplinary science content course includes a module in life science, physical science, earth science, and space science. Each module addresses state standards for licensure and includes state standards-based lessons they would teach in elementary classrooms. For example, lessons in life science included life cycles of plants and animals or in earth science lessons on the water cycle. Within each session of the course, technology was infused, such as coding, robotics, 3D printing, and virtual simulations. For example, when learning about the roles of organisms (producers, consumers, and decomposers), students coded a program showing the transfer of energy in the ecosystem. Another example when learning the water cycle, students coded a robotic device to navigate through the water cycle explaining the actions of water at each step. Each class session featured hands-on, cooperative investigations and lessons that candidates could use in their future classrooms.

In addition to developing a new multidisciplinary science course, the elementary science pedagogy class was also modified to enhance the elementary preservice teachers' ability to plan and teach science content using appropriate technology in a field experience. In the field experience, students were paired with cooperating teachers in first grade through fifth grade with licensed elementary cooperating teachers. The students worked with cooperating teachers to identify science standards and develop a technology-infused unit that was implemented during the field experience. The field placement was approximately two weeks, and each unit included science lessons that aligned to state standards that integrated coding and robotics. For example, in a first-grade lesson, students learned about hearing, tasting, and seeing, which was correlated to the Kibo robot. The Kibo robot has different sensor blocks that can be programmed to see the light (eye) and hear a sound (ear). In second-grade lessons, the Dash robot was coded by students to find the correct habitat for a specific animal by using cards and a map on the ground with various habitats. The robot and tasks were chosen based on the standards and the grade level taught. Previous field experiences did not require integrating technology to teach content, and the content was selected by the cooperating teacher. During the two-week field experience, students reflected on their practices with the instructor. Students were also required to videotape the lesson for further reflection.

## Purpose of the Study

The purpose of this study was to investigate the impact of a new multidisciplinary science content course and technology-infused field experience on elementary preservice teachers' perceived technological, pedagogical, and content knowledge (TPACK); and their overall confidence in teaching with technology. The research question guiding this study is: What impact do the elementary multidisciplinary science content course and field experience with technology have on elementary preservice teachers' perceived knowledge and confidence in teaching science content with technology?

## Methods

### Participants

The study utilized a quasi-experimental design based on the course students enrolled in for content preparation. This method was chosen because the course sequence students enrolled was not random; therefore, we could not utilize a true experiment. Participants included 127 of the 136 elementary preservice teachers enrolled in either general discipline-specific science (DS) courses or the new multidisciplinary science (MS) content course over six semesters. The sampling was purposive to include all elementary education candidates who voluntarily participated at the end of the licensure program. Data sets were analyzed by the science course sequence completed rather than by the cohort. Fifty-nine participants completed the DS course and field experience without a technology requirement, and 68 participants completed the MS course and technology-infused field experience. For comparative reasons, the nine students who took science courses outside the institution were not included in the analysis.

### Data Collection

Upon completing the licensure program, study participants' perceived technological, pedagogical, content knowledge was assessed using the Survey of Preservice Teachers' Knowledge of Teaching and Technology. The survey was developed and demonstrated an internal consistency reliability (coefficient alpha) ranging from .75 to .92 for the seven TPACK subscales (Schmidt et al., 2009). The survey consists of 54 Likert-scaled statements about Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK) Pedagogical Content Knowledge (PCK), and Technological Pedagogical Content Knowledge (TPACK). Response categories are "strongly agree," "agree," "uncertain," disagree," and "strongly disagree." Additionally, open-ended questions that asked candidates to describe their confidence and ability to integrate technology and episodes where they integrated technology in effective ways were also included. Participation in the study was voluntary and anonymous. Students accessed the survey online using an electronic device (computer, tablet, or phone).

### Data Analysis

A mixed-methods approach was used to evaluate the outcomes of the two different course sequences. A mixed-method approach can provide a more comprehensive picture of the data compared to a single design (Morse, 2010). Quantitative and qualitative data were collected in a survey. Quantitative analyses included descriptive statistics, t-tests, and Levene's test to assess the equality of variances for the two groups. Likert-scale items were initially scored based on guidelines provided by Schmidt et al. (2009) and were exported into Excel and the Statistical Package for the Social Sciences (SPSS), where means and standard deviations were calculated for each TPACK domain and as a whole. Data sets were not analyzed for the content-specific questions related to math, social studies, and language arts since this was not the focus of the course. Open-ended responses describing the confidence in teaching with technology for participants were coded into four categories, highly confident, confident, fairly confident, and not confident. Open-ended responses describing specific episodes where elementary preservice teachers themselves effectively combined content, technologies, and teaching approaches in a classroom lesson were read repeatedly to generate a list of episodes that demonstrated specific uses of technology with content and pedagogy.

## Results

### Quantitative Data

Descriptive statistics were calculated to perform an independent t-test to compare the means of the general discipline-specific (DS) course vs. multidisciplinary (MS) course. The means for each area of the TPACK were then calculated, including Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and Technological Pedagogical Content Knowledge (TPACK). For the purpose of this study the Content Knowledge (CK), Technological Content Knowledge (TCK), and Pedagogical Content Knowledge (PCK) were only analyzed for science. Levene's Test for equality of variances indicated in all cases that equal variances were assumed, TK ($F = 2.34, p = .156$), PK ($F = .418, p = .519$), CK ($F = 1.09$, $p = .297$), TPK ($F = .985, p = .323$), PCK ($F =. 018, p = .895$), and TPACK ($F = .507, p = .478$). The mean TK, CK (Science), PCK(Science), TPK, TPK(Science), PCK (Science), and overall TPACK all showed a significant difference from the old course sequence to the new course sequence. The PK was the only measure that was not significant, see Table 1. The greatest change in means from the DS (3.87) course to the MS (4.22) was with content knowledge in science.

**Table 1**

*Descriptive Data and Results of t-test of Discipline-Specific (DS) Course vs. Multidisciplinary Science (MS) Course*

| **Factor** | **Mean DS** (N=59) | **SD** | **Mean MS** (N=68) | **SD** | **t** | **Sig. (2-tailed)** |
|---|---|---|---|---|---|---|
| TK | 3.79 | 0.46 | 4.12 | 0.53 | -3.77 | .000* |
| PK | 4.33 | 0.39 | 4.43 | 0.38 | -1.57 | .119 |
| CK Science | 3.87 | 0.58 | 4.22 | 0.42 | -3.90 | .000* |
| TPK | 4.22 | 0.46 | 4.40 | 0.39 | -2.37 | .019* |
| TCK Science | 4.00 | 0.64 | 4.40 | 0.52 | -3.84 | .000* |
| PCK Science | 3.95 | 0.62 | 4.22 | 0.45 | -2.82 | .006* |
| TPACK | 3.97 | 0.45 | 4.21 | 0.48 | -2.84 | .005* |

### Qualitative Data

For this study, we analyzed two open-ended questions from the survey. First, participants in the survey were asked to describe their confidence and ability to combine content and technology in teaching a classroom lesson. Responses were coded as 1-not confident, 2-somewhat confident, 3-confident, and 4-very confident. Researchers coded the responses independently with agreement on 86% of the responses. Through discussion, 100% agreement was achieved. Five responses were eliminated because they did not address the prompt and could not be rated. A comparison of participants' confidence by percentage is presented in Table 2. Results indicated a high and very high level of confidence in participants regardless of whether they took the discipline-specific science course (DS) (79%) or multidisciplinary science course (89%), but a shift in the percentage of very confident rose from 31% in the DS to 49% in the MS.

**Table 2**

*Comparison of Confidence by Percentage in DS vs. MS*

| | **DS** (n=52) | **MS** (n=63) |
|---|---|---|
| Not Confident | 4% | 0% |
| Somewhat Confident | 17% | 11% |
| Confident | 48% | 40% |
| Very Confident | 31% | 49% |

Analysis of responses to open-ended prompts in which participants described specific times they effectively combined content, technologies, and teaching approaches in a classroom, indicated a relatively limited understanding of TPACK in both groups (DS and MS). Many participants described the use of presentation tools, apps, quiz tools, games, video-recording, and content-specific software. Overall, almost no participants demonstrated the ability to describe how they integrated the use of technology, pedagogy, and science content in meaningful ways. For example, they did not provide examples where they were coding or using robotics. Most instances of technology integration were to enhance lessons, such as using a presentation tool rather than transform the learning in new ways by coding, using robotics, and interacting or collaborating globally.

## Discussion

The complexity of preparing elementary preservice teachers with the required science and technology knowledge can challenge teacher preparation programs. Our decision to create a multidisciplinary science content course and modify a field experience to include a technology-based teaching experience appears to positively impact candidates' perceived technological, pedagogical, and content knowledge. Specifically, candidates who participated in the new multidisciplinary science content course and technology-embedded field experience completed the program with higher perceived CK, TK, PCK, TPK, PCK, and TPACK. Pedagogical knowledge (PK) is the only domain in which participants did not show a statistically significant increase, but the overall mean was the highest mean in both groups compared to the other TPACK domains. One significant finding was that the greatest change in mean was found with the participants' perceived science content knowledge (CK Science). This course design shows promise in the multidisciplinary approach compared to the discipline-specific approach. This is similar to results reported by Knaggs and Sondergeld (2015), where students enrolled in a multidisciplinary science content course before a science pedagogy course, expressed gains in content knowledge and pedagogical knowledge that would help them to become effective science teachers.

The results also indicate that participants' confidence in their ability to integrate technology into instruction increased. While candidates' confidence in their technology integration skills was high for all participants, an increase of 18% of candidates who enrolled in the multidisciplinary course indicated being very confident, compared to the discipline-specific course sequence. The increased confidence may be attributed to the programmatic changes, including creating a multidisciplinary science content course taught by a professor with advanced training in science and pedagogy, and modifications to the elementary science field experience to include opportunities for candidates to teach with technology. These results are consistent with other research that indicate observing, designing, and teaching technology-based lessons were instrumental in developing TPACK (Ertmer & Ottenbreit-Leftwich, 2010; Buss et al.,, 2018).

Although confidence does not automatically ensure effective technology integration, research suggests that technological self-efficacy is a factor. According to Bandura (1997), individuals' self-efficacy "influences the courses of action people choose to pursue, how much effort they put forth in given endeavors, how long they will persevere in the face of obstacles and failures, their resilience to adversity, … and the level of accomplishments they realize" (p. 3). Educational technology researchers have utilized Bandura's work when exploring factors that impact preservice teachers' pedagogical uses of technology. Specifically, self-efficacy has repeatedly been identified as a key determinant of novice educators' use of technology in the classroom (Bauer & Kenton, 2005; Ertmer & Ottenbreit-Leftwich, 2010). While participants' TPACK confidence was high, the evidence suggests most were not yet able to identify examples of meaningful ways that they, or their cooperating teachers, used technology to expand elementary students' knowledge of significant science concepts or skills. Participants' limited ability to identify meaningful uses of technology occurred even though the science content professor regularly modeled how to use productivity applications, coding, 3-D printing, and digital simulations to foster scientific thinking and understanding. Buss et al. (2017) also found that most teacher candidates in their study planned to use technology in routine, non-transformative ways, leading to the conclusion that the pedagogical uses of technology may follow a developmental trajectory. These findings are similar to Mouza et al. (2013), who found that preservice teachers recognize the value of technology but have limited knowledge of how to use technology in ways that deepen content knowledge. Not only do elementary education candidates need opportunities to plan and teach inquiry-based science lessons that include technology, but they also need time to reflect on how technology supports the teaching of science through inquiry compared to other traditional uses of technology, such as showing a video or PowerPoint to present content (Polly & Binns, 2018).

## Limitations

One limitation of the current study is that self-report scales were used to measure participants' TPACK and confidence in teaching with technology. Respondents may overstate their confidence because they think it is desirable, particularly when the researcher is also the course instructor. In addition, the method of data collection may have impacted participants' responses. The survey was administered during the last official programmatic meeting of the semester. Limited time to prepare written responses and the excitement of being finished with the program may have negatively impacted the care candidates took in answering open-ended questions. In future studies, interviewing preservice teachers may generate responses with more depth and might produce more robust data. A third limitation of our study is that because we did not gather data before and after student teaching, we do not know how this signature experience impacted participants' perceived TPACK and technological self-efficacy. Finally, caution should be exercised in forming generalizations based on the results of this study due to the small sample size.

## Future Recommendations and Next Steps

The initial results of this study have promising implications for teacher preparation programs that are interested in integrating technology within science content and pedagogy courses and requiring a field placement that includes the use of technology. While we are hopeful about the positive impact of our model on preservice teachers' perceived TPACK and technological self-efficacy, we see areas for additional programmatic modifications that may enhance candidates' ability to identify and deliver meaningful technology-infused elementary science lessons. Moving forward, we plan to introduce teacher candidates to the TPACK framework in science content and pedagogy courses. Research suggests that structuring learning opportunities that allow them to reflect on and analyze the complex interplay of technological, pedagogical, and content knowledge may enhance their ability to deliver science lessons that show evidence of understanding a more sophisticated TPACK (Ertmer & Ottenbreit-Leftwich, 2010).

Additionally, we think training cooperating teachers to model, support, and help facilitate opportunities for technology inclusion to improve elementary preservice teachers' technology integration in science content teaching may prove helpful. All teacher candidates in our study demonstrated the ability to plan and teach lessons on coding and robotics in area elementary schools during a pre-student teaching field experience. These lessons, developed with the support of the pedagogy instructor, evidenced strong TPACK. By comparison, technology integration during student teaching remained basic using apps, quiz tools, and presentation software. While various factors may explain the difference, we wonder if cooperating teachers received TPACK training, would candidates be given the support needed to use digital tools in more meaningful ways.

Lastly, to evaluate the success of the teacher preparation program in TPACK, we need to observe and assess graduates of our program to determine if the preparation was adequate and if TPACK practices are occurring in their current practice. Understanding how teacher candidates' perceived TPACK and self-efficacy impact their long-term teaching practices is key to evaluating the effectiveness of our program modifications.

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**Diana Fenton** (dfenton@csbsju.edu) has been a science educator for over 20 years. She is currently an Associate Professor at the College of St. Benedict and St. John's University in Minnesota. Her research interests include technology integration, equity, and science misconceptions. Her teaching and instruction include K-12 preservice teachers in science as well as graduate courses to inservice teachers in curriculum and instruction.

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