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The Impact of a GenCyber Camp on In-service Teachers' TPACK

Abstract

The purpose of this study was to examine the impact of a GenCyber camp curriculum on teachers' technology, pedagogy, and content knowledge (TPACK). The camp was designed to engage participants in developing the knowledge and skills to incorporate GenCyber Cybersecurity First Principles and GenCyber Cybersecurity Concepts (GenCyber, 2019) into their curriculums. Participants (37 middle and high school teachers from a variety of disciplines) attended one of two weeklong camps held at a Midwestern liberal arts university. Using the TPACK Self-Reflection and TPACK Self-Assessment Surveys, pre- and post-camp data were collected from participants. Findings indicate that participants demonstrated an increase in all domains of the TPACK framework from pre- to post-survey. The greatest increase was in Technological Pedagogy Knowledge (TPK) (0.57), followed by Pedagogical Content Knowledge (PCK) (0.51), and Technological Pedagogical Content Knowledge (TPACK) (0.46). GenCyber participants also demonstrated an average increase in pre- and post-test scores in all areas on the TPACK Self-Assessment Survey Results; however, individual results were mixed. The majority of participants (n=21), sixty percent, saw an increase in composite score from pre- to post, whereas 12 participants' (34%) scores decreased from pre- to post, and two (6%) stayed the same. Findings indicate the GenCyber Camp provided in-service teachers with the knowledge and skills necessary to incorporate GenCyber Principles and Cybersecurity Concepts into their curriculum. Recommendations for teacher professional development on cybersecurity are made.

Keywords

GenCyber, cybersecurity, TPACK, in-service teachers

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Introduction

"Cyberattack Forces a Shutdown of a Top U.S. Pipeline" (Sanger, Krauss, & Perloroth, 2021), "The Cybersecurity 202: Schools Are Another Prime Ransomware Target" (Marks, 2021), and "U.S. Formally Links Russia to Massive 'Ongoing' Cyber-Attack: Scope of Hacking Unclear" (Johnson, 2021). These recent headlines reflect the growing threat of cyberattacks on individuals, companies, and government agencies—cyberattacks that are predicted to result in damages totaling $6 trillion USD globally in 2021 and grow to $10.5 trillion by 2025 (Morgan, 2021a). The increasing ubiquity of cyberattacks in the U.S. has demonstrated the importance of cybersecurity. However, the 2019/2020 Official Annual Cybersecurity Jobs Report indicates 3.5 million unfilled cybersecurity jobs in 2021—an increase of 350 percent since 2013 (Morgan, 2021b). To meet the demands from both the government and private sectors for qualified cybersecurity professionals, it is essential that K-20 schools attract students to study cybersecurity and pursue cybersecurity careers (Hernandez, Qu, Yuan, & Xu, 2020).

The GenCyber Teacher Camp is a weeklong professional development designed to prepare middle and high school teachers with the skills necessary to teach their students the GenCyber Principles and Concepts and ignite in students a passion for cybersecurity that will lead them to pursue higher-education degrees and professions in the field. Over the course of the weeklong camp, teachers from across the state attended focused sessions promoting inquiry-based learning, discourse, and collaborative learning. These activities assisted teachers in interactively reflecting on best practices in STEM education while learning and applying the content of GenCyber Principles and Concepts within the context of their own field of study. For example, participants worked through a series of ethical and moral dilemmas related to cyber citizenship and technology, examined cyber vulnerabilities, and planned how they could increase students' awareness and understanding of the issues. Additional activities throughout the week included Micro:bit encoding, Sphero programming, 3D printing, cyber law with a guest speaker from a local law firm, cybersecurity as a career with a guest speaker from a local bank, and cyber-crime with guest speakers from the FBI.

In order to effectively integrate these principles and technologies into their classrooms, participants needed to develop their technology literacies—understanding how these principles and technologies could be used to support the teaching of specific content knowledge and improve student learning. GenCyber refers to this as “teaching readiness”—the ability to transfer what teachers learn to their practice (GenCyber Website: Resources). To assess the effectiveness of camps in preparing teachers to successfully integrate principles and technology, the GenCyber Program uses a model grounded in the work of Shulman and Shulman (2004), which does not specifically address the interplay between pedagogy, content knowledge, and technology. Mishra and Koehler, building on the work of Shulman (1986, 1987) and Shulman and Shulman (2004), added technology (T) to Shulman’s pedagogy content knowledge model (PCK) to develop the technology, pedagogy, and content knowledge (TPACK) framework for training teachers and evaluating their effectiveness in integrating technology to support instruction and student learning. To develop “teacher readiness” in participants, the camp curriculum was aligned with the TPACK framework. According to Davies (2011), the most effective method for developing technological literacies is through guided practice and authentic application. Participants in the GenCyber camp were introduced to new technologies through modeling, and over the course of the week, teachers learned how, when, and why to use these technologies to support instruction and student learning in their specific content areas. They designed lessons to demonstrate the integration of technologies to support GenCyber Principles.

Despite the TPACK framework being characterized as essential to enabling teachers to implement instructional technologies in their teaching (Voogt & McKenney, 2015), there is a lack of research on evaluating the effectiveness of GenCyber camps’ impact on participating in-service teachers’ TPACK. The purpose of this study is to understand the impact of the camp on teachers’ GenCyber technology literacy and answer the questions:

1. Is participation in the GenCyber camp correlated to changes in participants’ technology knowledge? If so, how?
2. Is participation in the GenCyber camp correlated to changes in participants’ content knowledge? If so, how?
3. Is participation in the GenCyber camp correlated to changes in participants’ pedagogical knowledge? If so, how?

Review of Literature
GenCyber Camps

GenCyber "strives to be a part of the solution to the Nation's shortfall of skilled cybersecurity professionals" through their three goals: "Ignite, sustain, and increase awareness of K12 cybersecurity content and cybersecurity postsecondary and career opportunities for participants through year-round engagement; Increase student diversity in cybersecurity college and career readiness pathways at the K-12 level; and Facilitate teacher readiness within a teacher learning community to learn, develop, and deliver cybersecurity content for the K-12 classroom in collaboration with other nationwide initiatives" (GenCyber Website). To accomplish these goals, GenCyber camps were started in 2014 with eight proof of concept camps. As of 2019, there have been over 123 camps with 15,545 students and 3,711 teachers participating (Dark, Daughterly, & Dark, 2020). Although GenCyber currently funds only student and teacher camps, historically there have been three types of camps: student, teacher, and combination student-teacher camps. Camps are funded by the National Security Agency, National Science Foundation, and other federal partners, so camps are free to all attendees (GenCyber CFP, 2019). GenCyber programs emphasize "hands-on, active learning and sound pedagogical practices. Successful GenCyber grant proposals must demonstrate both the intent and the capability to provide engaging, long-lasting, and substantial learning experiences to improve cybersecurity awareness, understanding and/or proficiency among diverse participants" (Payne, Abegaz, & Antonia, 2016, p. 2).

Impact of GenCyber Camps

To increase cybersecurity awareness, understanding, and proficiency, teachers must be technologically literate. GenCyber defines technology literacy as "teacher readiness"—the dispositions and ability to integrate what they have learned into their teaching practice (GenCyber Website: Resources). Based on the work of Shulman and Shulman (2004), GenCyber identifies three critical factors in determining teachers' "ability to transition what they learn to their teaching practice: 1) teacher knowledge to teach content, 2) teacher vision to teach the content, and 3) teacher motivation to teach content" (GenCyber Website: Resources). To achieve readiness, teachers must develop three types of knowledge: content knowledge (knowing what to teach), curricular knowledge (knowing when to teach it); and pedagogical content knowledge (knowing how to teach it)

(GenCyber Website: Resources). Findings from research conducted by GenCyber indicate that the camps are impacting participating teachers' readiness to teach GenCyber concepts to their students. Of the teachers attending camps from 2017-2019, nine hundred seventy-three (36.5%) report teaching cybersecurity or cyber safety the following school year as a result of attending GenCyber. Furthermore, since 2017, the percentage of participants reporting teaching GenCyber or cyber safety has increased each year from 29% in 2017 to 39% in 2018, and 42% in 2019. Findings from research conducted by GenCyber indicate that 69% of 2018 participants in GenCyber camps reported that they left the camp ready, willing, and able to teach cybersecurity. The percentage increased to 73% for 2019 attendees. In fact, 39% of teachers in 2018 and 42% in 2019 reported teaching cybersecurity or cyber safety the following year (Dark, Daugherty, & Dark, 2020).

Outside of the research conducted by the GenCyber Program, there has been little research on the impact of camps on participants' practice. This lack of research is significant especially considering there have been 123 camps with 3,711 teachers participating. Most of the research that has been conducted has been via surveys completed by participants at the end of camps and supports the findings by the GenCyber Program that the camps have a positive impact on teachers' practice. Li, Tian, and Jin (2022) pre- and post-tested participants and found a statistically significant difference in the teachers' content knowledge of cybersecurity topics, which along with qualitative feedback, supported the finding that the camp had prepared participating teachers with the knowledge they would need to integrate cybersecurity topics into their classrooms. A 2020 study by Ivy, Kelley, Cook, and Thomas (2020) found that 85% of teachers participating in a 2019 camp reported "relatively high expectations they would be integrating cybersecurity into their lessons" (p. 8); however, findings did suggest that camp attendees had some concerns about finding the time and resources to integrate cybersecurity into their curriculums. Burrows and Borowczak (2019) found that 87% of the teachers attending their camp reported that they were planning to integrate cybersecurity into their classes, and Harmon, et al. (2020) found that 17 of 19 (89%) teachers planned to incorporate the cybersecurity concepts they learned in the GenCyber camp into their courses. Finally, seven out of nine (77%) teachers in a 2017 camp indicated that they would be integrating the camp concepts into their classrooms, which the research attributed to increased self-efficacy on the part of these participants (Ivy, Kelley, Cook, & Thomas). Outside of the research conducted by the GenCyber Program, there is a gap in the research on the long-term impact of camps on teacher integration of cybersecurity or cyber safety into their curriculums.

Framework

GenCyber camps work with the participating teachers to build their technology literacy or teacher readiness in GenCyber Principles and Concepts and cyber security. One way we attempted to accomplish this is by using the Koehler and Mishra (2009) Technology, Pedagogical, and Content Knowledge (TPACK) framework for developing technology skills and expertise (Figures 1).

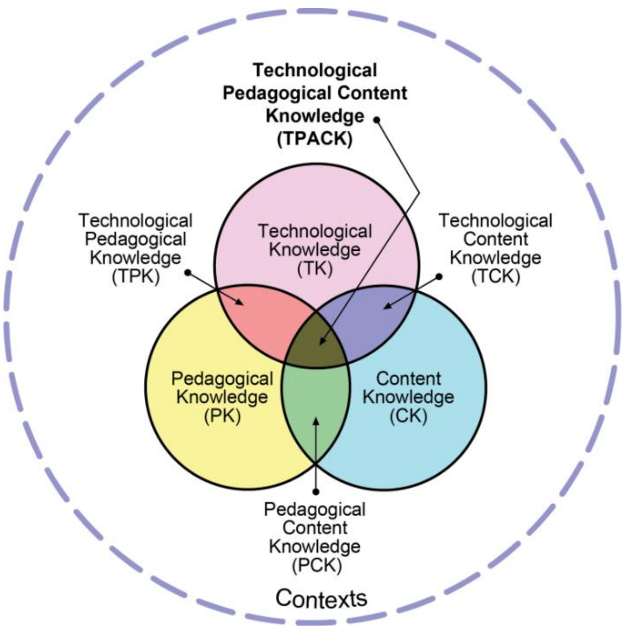

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Figure 1: TPACK Framework

TPACK is a theoretical framework for teacher technology integration. Developed by Koehler and Mishra, TPACK built on the Shulman (1986, 1987) and Shulman and Shulman (2004) framework used by GenCyber (Koehler, Mishra, & Cain, 2013). By adding technology (T) to the Shulman and Shulman framework of pedagogy (P) and content knowledge (CK), the TPACK framework "aims to describe the kinds of knowledge needed by a teacher for effective pedagogical practice in a technology-enhanced learning environment" (Lehiste, 2015, p. 19). Seven knowledge domains exist within the TPACK framework:

1) technological knowledge (TK) - knowledge of various technologies,
2) content knowledge (CK) - knowledge of the subject matter being taught to students,
3) pedagogical knowledge (PK) - knowledge of teaching methods, lesson planning, assessment, and general classroom management skills,
4) pedagogical content knowledge (PCK) - knowledge of how to teach content-based material to students,
5) technological content knowledge (TCK) - knowledge of how to select and use different technologies to communicate content knowledge,
6) technological pedagogical knowledge (TPK) - knowledge of using technology to implement different teaching methods, and
7) technological pedagogical content knowledge (TPACK) - knowledge of using technology to implement teaching methods for diverse types of subject matter content (Koehler & Mishra, 2009).

There have been numerous studies using TPACK as the theoretical framework for teacher training (Hong & Stonier, 2015; Miguel-Revilla, Martinez-Ferreira, & Sanchez-Agusti, 2020; Oda, Herman, & Hasan, 2020). From this research, we know that effective integration of technology in instruction using the TPACK framework is dependent on teachers' developing a deep understanding of how each of the components (e. g., technology, pedagogy, and content knowledge) interact with each other" (Koehler, Mishra, Kereluik, Tae, & Graham, 2014). The TPACK framework assists teachers in understanding "(a) the technology tools themselves, combined with (b) the specific affordances of each tool that, when used to teach content, enable difficult concepts to be learned more readily, thus resulting in the achievement of meaningful student outcomes" (Angeli & Valanies, 2009, cited in Ertmer & Ottenbriet-Leftwich, 2010, p. 259).

TPACK has also been used to assess the growth in technology literacy of participants in professional development training (Oda, Herman, & Hasan, 2020; Lehiste, 2015). In their review of literature on the TPACK framework, Moreno, Montoro, and Colon (2019) found TPACK to be a solid framework for "obtaining a good diagnosis of teachers both in their initial and permanent training" (p. 8). Research supports the use of a pre- and post-assessment to evaluate the effectiveness of training on the development of teachers TPACK (Lehiste, 2015; Chai, Koh & Tsai, 2010).

Previous research on GenCyber professional development has found that the training positively impacted teachers' understanding and application of the TPACK framework. For example, a 2016 GenCyber camp (Ivy, Lee, Fanz, &

Crumpton, 2019) pre- and post-tested participants using the TPACK Self-Reflection and TPACK Self-Assessment Surveys to assess participants' growth. Results demonstrated significant growth, 15% score increase from pre- to post-test, in participating teachers' TPACK across themes. It is notable that the 2016 GenCyber Teacher camp used a different camp curriculum than the 2018 GenCyber Teacher camp, but both camps had a common thread of including teachers from a variety of disciplines in a weeklong experience integrating opportunities for technological growth, TPACK growth, and content exploration with cyber and programming concepts. This multidisciplinary approach provides teachers with the opportunity to engage cybersecurity concepts in the context of their own comfort zones and to build self-efficacy (Ivy & Franz, 2017).

There is a lack of research in the literature on the impact of GenCyber camps on participants' Technology, Pedagogy, and Content Knowledge of GenCyber Principles and Concepts. Although GenCyber has conducted research on the "teacher readiness" of attendees, their model is grounded in the work of Shulman and Shulman (2004) and lacks a specific focus on the inclusion of technology within the integration framework. Integrating technology into the classroom to support instruction and student learning requires teachers to develop an understanding of the complex interplay between technology, pedagogy, and content knowledge (Koehler, Mishra & Yahya, 2007). As a result, many teachers struggle to effectively integrate technology (Voogt & McKenney, 2018). Evidence of this issue can be found in the findings of the GenCyber Program's 5-year report, which found that only 36.5% of teachers who attended a GenCyber camp reported teaching cybersecurity or cyber safety the following school year (Dark, Daugherty, & Dark, 2020). As Voogt and McKenney (2018) point out, TPACK is essential to preparing teachers to ingrate technology into their classrooms because it "enables them to select and use hardware and software, identify the affordances (or lack thereof) of specific features and use the tools in pedagogically appropriate and effective ways" (p. 72). This study expands on previous work to examine the impact of one GenCyber teacher camp experience on in-service teachers' TPACK.

Purpose and Research Questions

The GenCyber camp provided middle and high school teachers across disciplines with opportunities to explore, first as learners and then as educators, cyber citizenship and programming, which are concepts with explicit connections to the GenCyber Principles. Teachers attending the GenCyber camp were introduced to each technology and GenCyber Concept or Principle through modeling and provided with opportunities to interact with the technology, both of which helped build participants' self-efficacy (Somekh, 2008; Ertmer, 2005). Participating teachers would take the knowledge and skills developed during the camp and integrate their lessons with them. TPACK provides a framework for assessing teachers' ability to successfully integrate technology. Teachers were administered a pre- and post- assessment using the TPACK Developmental Model Self-Assessment Survey. The purpose of this study is to compare pre- and post-assessments to determine the impact of the camp on participants' TPACK knowledge.

1. Is participation in the GenCyber camp correlated to changes in participants' technology knowledge? If so, how?
2. Is participation in the GenCyber camp correlated to changes in participants' content knowledge? If so, how?
3. Is participation in the GenCyber camp correlated to changes in participants' pedagogical knowledge? If so, how?

Methods

Research Design

Guided by the recommendations of Creswell (2013), we used the survey approach to investigate the impact of the weeklong GenCyber camp on in-service teachers' Technology, Pedagogy, and Content Knowledge (TPACK). Survey research was the preferred method of data collection because of its economy, rapid turnaround time, and the standardization of the data (Babbie, 2012). Participating teachers completed a pre- and post- assessment. The survey is discussed in the Data Source section.

Participants

The instructional team included three primary instructors (two classroom teachers and one university faculty member) and two assistants (pre-service teachers). Participants were recruited primarily from two school systems in the Midwest. The first is a large, diverse, urban system with more than 100,000 students. The second is a large private system with over 20,000 students. Information and applications were distributed through the Professional Development Coordinators in each system. Applicants from other school systems heard about the camp through word of mouth. Sixty-one teachers applied to participate in the camp. Participants were selected from applicants with attention to establishing a diverse (e. g. age, gender, race, rural/urban, content area) group of educators who serve across various systems. Applicants were sorted based on their level of diversity and then selected based on the order in which they applied. The initial goal of the camp was to reach forty teachers, 20 per week; however, 37 teachers participated, 21 in the first week and 16 in the second week. (Four participants withdrew or did not show up for the second week of camp.) For each week, approximately 50% of the participants were middle school teachers and 50% high school teachers. Participants represented 11 school systems/districts within driving distance of the professional development site.

Data Sources and Collection

The TPACK Developmental Model Self-Assessment Survey was co-developed and adapted by the second author and based on the themes and subthemes of the TPACK Standards and Development Model. These themes included Curriculum and Assessment, Learning, Teaching, and Access. Subthemes for Curriculum and Assessment include curriculum and assessment. Subthemes for Learning included subject matter and conception of student learning. Subthemes for teaching include subject matter, instructional approaches, classroom environment, and professional development. Subthemes for access included usage, barriers, and availability (Niess, et al., 2009). The TPACK Self-Assessment survey included 11 categories, adapted from the themes and subthemes of the TPACK development model. For each category, five levels of descriptors provided insight into the TPACK levels for participants. The five levels were Recognizing, Accepting, Adapting, Exploring, and Advancing. Each level was correlated with a numerical value from one to five, and the sum of the criteria provided an indexed TPACK rating for each iteration of the TPACK Self-Assessment survey. All participants completed the survey prior to the start of the camp and at the end of the camp. In both instances, participants accessed the online Google Forms survey. No login was required, and responses were collected anonymously with identifiers only used for pairing pre- and post-responses. No responses were connected to participants' names. Participants completed the survey in one sitting. The approximate time for completion was 10-15 minutes, depending on the individual. Data were exported from Google Forms as an Excel spreadsheet. The resulting data were analyzed, and descriptive statistics were calculated to identify frequencies and means; other statistical tests were administered as needed.

Results

Results from the TPACK Self-Reflection Survey (Appendix A) demonstrated an increase in all domains of the TPACK framework from pre- to post-test (Table 1). Scores for each assessment were calculated by assigning a value to each response with the lower-level responses beginning at 1 and increasing. This procedure provided a quantitative measure of responses for each item. The greatest increase was in Technological Pedagogy Knowledge (TPK) (0.57), followed by Pedagogical Content Knowledge (PCK) (0.51), and Technological Pedagogical Content Knowledge (TPACK) (0.46). The least growth was apparent in the areas of Content Knowledge (CK) (0.2), followed by Pedagogical Knowledge (PK) (0.31).

Technology, Pedagogy, and Content Knowledge (TPACK) Domain	Pre-Test	Post-Test	Change
CK	3.26	3.46	0.2
PK	2.94	3.26	0.31
TK	3.09	3.4	0.4
TCK	2.94	3.34	0.4
PCK	2.74	3.17	0.51
TPK	2.43	3	0.57
TPACK	2.63	3.09	0.46

Table 1: TPACK Self-Reflection Survey: Averages by Domains (score range 0 – 4)

The TPACK Self-Assessment Survey (Appendix B) has four themes with eleven total sub-themes, as previously described: Curriculum, Assessment, Learning (Content Learning Change and Conceptions of Student Thinking), Teaching (Content, Instruction, Environment, and Professional Development), and Access (Usage, Barriers, and Availability). Initial analysis of participants' responses revealed mixed results. Some participants' scores increased from pre- to post-test, while others decreased. 60% of participating teachers (n=21) saw an increase in composite score from pre- to post, whereas 12 participants' (34%) scores decreased from pre- to post, and two (6%) stayed the same. Additional analysis did not reveal any trends or patterns that would explain the inconsistencies in post-test results; however, we noted the heterogeneous makeup of our participants regarding content area, teaching levels, and experience with technology may have been a factor.

Despite the mixed results for individual scores, GenCyber participants demonstrated an average increase in pre- and post-test scores in all areas on the TPACK Self-Assessment Survey (Tables 2 & 3). Scores for the second part of the assessment were calculated similarly to Part A. The lowest level responses were assigned a value of 1, increasing up to a 5 for responses which aligned with the Advancing level. For each theme, each participant's responses were averaged, providing a value (ranging from 1 - 5) for each subtheme. The cumulative score represents the sum of the scores from each subtheme. The area with the greatest increase from pre- to post- was in the Access subtheme of Availability (0.85) followed by Curriculum (.54) and the Learning subtheme Content Learning (0.514) and Teaching Environment (0.51). The least amount of change occurred in Learning Conception of Student Thinking (0.057), which was followed by Access subtheme Usage (0.17) and Barriers (0.14). With all scores combined, the average change for composite scores from pre- to post- was 3.17, or 7.2% (with 44 possible points). The average score on the pre-test was 28.8 and the average score on the post-test was 31.97. The average change was 3.17 (Table 3). The t-test comparisons of the themes and subthemes are summarized in Table 4. These results indicate that only the Access: Availability score was significant at 0.02.

N=35	Pre				Post				Change (Mean)
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Curriculum	2.63	1.29	1	4	3.17	1.12	0	4	0.54
Assessment	2.43	1.67	0	4	2.91	1.2	0	4	0.48
Learning: Content Learning	2.57	1.54	0	4	3.09	1.15	0	4	0.51
Learning: Conception of Student Thinking	2.89	1.39	0	4	2.94	1.57	0	4	0.057
Teaching: Content Learning	2.63	1.63	0	4	3.09	1.31	0	4	0.45
Teaching: Instructional	2.60	1.38	0	4	2.89	1.39	0	4	0.28
Teaching: Environment	2.43	1.56	0	4	2.94	1.41	0	4	0.51
Teaching: Professional Development	2.97	1.4	0	4	3.2	0.93	1	4	0.22
Access: Usage	2.66	1.33	0	4	2.83	1.4	0	4	0.17
Access: Barrier	2.91	1.12	0	4	3.06	1.14	0	4	0.14
Access: Availability	2.09	1.62	0	4	2.94	1.24	0	4	0.85

Table 2: TPACK Self-Assessment Survey: Summary of Results by Themes (Sub-themes)

Assessment	Mean
Score Pre	28.8
Score Post	31.97
Score Change (Mean)*	3.17
*** P-value = 0.242**	

Table 3: Summary of Pre- to Post- Score Changes

T-Test Comparison	P-value
Curriculum	0.06
Assessment	0.17
Learning: Content Learning	0.12
Learning: Conception of Student Thinking	0.87
Teaching: Content Learning	0.2
Teaching: Instructional	0.39
Teaching: Environment	0.15
Teaching: Professional Development	0.43
Access: Usage	0.6
Access: Barrier	0.6
Access: Availability	0.02

Table 4: T-Test Comparison of Final Score Means

Qualitative data reveals several themes. Part A of the TPACK survey asked participants to reflect on and rate their confidence regarding each area of the

TPACK framework (CK, PK, TK, TCK, PCK, TPK, and TPACK). Davies (2011) indicates that to become technologically literate, teachers must first become aware of new technologies (awareness). Next, they must learn how to use the technology (praxis), and finally, learn when and how to use it in their classrooms to support student learning (phronesis). Participants' comments indicate that to some degree, they engaged in each of these stages during the GenCyber Camp. For example, participants' comments indicated a lack of awareness about technologies; "Technology changes so quickly that I feel like I fall behind on new strategies/tools that are available." The GenCyber camp introduced participants to new technologies and taught how to use (praxis) and integrate them into their classrooms (phronesis), which resulted in increased self-efficacy in GenCyber tools and concepts. Participants stated, "I feel more confident in knowing more about cyber security and how it relates to not only school (staff and students) but also to myself on a personal level" and "I now know how to integrate these technologies into my curriculum."

Additional themes emerged from Part B of the TPACK survey. This portion of the survey explored participants' beliefs and practices regarding technology in their classrooms. As Ertmer (1999) notes, teachers' beliefs can be a second-order barrier to technology integration. The themes that emerged were also connected to first-order barriers (Ertmer, 1999; Bitner & Bitner, 2001). For example, participants indicated a lack of access to technology; "I would use more technology in my room, but our school has competition for available technology" and "…this will be my first year with reliable access to technology." GenCyber camp attendees also pointed to a lack of training as a barrier to their use of technology. Comments included "I am unsure of how to appropriately intertwine TPACK so that students receive adequate explicit instruction as 21st-century learners and strong readers & writers," "I would like to learn new technologies and ways to teach that I am not currently familiar with," and "I would love to grow more confident in my own technology skills…." Participants also noted time as a barrier to technology use. Teachers stated that "The hardest part about pursuing professional development is resources (having the time to leave my building and paying for registration fees, etc. are barriers)" and "Unfortunately, when I get to the point, I feel crunched for time, technology is often the first thing to get pushed out."

Limitations

Although this study contributes to our overall understanding of the impact of GenCyber camps on in-service teachers TPACK, there are limitations characteristic to the methods used. For example, the survey is an adapted version of an assessment which focused on mathematics specific content and aligned to a mathematics TPACK development model and not cyber and programming content. An additional limitation is that survey results relied on self-report data; therefore, participants may not have answered honestly or accurately; furthermore, no method exists for verifying their answers. The generalizability of the study is limited by the population of the study, who are in-service teachers from one state. If the population were larger, involving additional states and/or regions of the U.S., perceptions could differ. These limitations confirm the necessity for further research.

Discussion

Analysis of data from the two surveys, TPACK Self-Reflection and TPACK Self-Assessment, revealed mixed results. While results demonstrated growth in each area of the TPACK framework (TPACK Self-Reflection Survey), scores indicated significant room for improvement in TPACK learning. Likewise, the average scores increased for each of the themes of the TPACK Self-Assessment Survey from pre- to post-test; however, analysis of the data did not provide any insights into why 34% of participants' scores actually decreased from pre- to post-test. It is possible that with the additional technological and technological pedagogical knowledge from the GenCyber experiences, teachers were more aware of the meanings of statements in the survey and thus provided a better indication at post-administration than they had initially. Furthermore, a comparison of results from the featured GenCyber camp with a previous GenCyber camp (Ivy, Kelley, Cook, & Thomas, 2020) makes clear the need for additional research on the pedagogical factors that contribute to positive impact on participants' learning.

As previously stated, participants' scores on the TPACK Self-Reflection Survey increased in all areas. The weeklong camp engaged participants in individual and collaborative activities to assist them in developing the necessary knowledge and skills to engage students in inquiry-based learning around the principles of cybersecurity. The teachers' culminating project was the development of GenCyber focused lessons in their content areas. An analysis of the instructional time dedicated to the TPACK themes over the course of the week did not shed any light on these findings—approximately 71% of the time was devoted to TK, 19% of time devoted to TPCK, and 9% of time devoted to TPK. Interestingly, participating teachers in a previous GenCyber camp demonstrated similar results. Like the current GenCyber teachers, these teachers were most confident about the TPCK and PCK themes and least confident about their content knowledge. Two additional points of interest were that Pedagogical Knowledge was second to last for the 2019 campers and second from the top with the 2015 group. In addition, the teachers from the previous GenCyber camp were more confident in all areas (Table 5).

2019 Knight Cyber Camp (Range 0 – 4)		2015 Bulldog Bytes Camp (Range 1 – 5)	
TPK	.57 (14.25%)	TPCK	.76 (15.2%)
PCK	.51 (12.5%)	PK	.72 (14.4%)
TPCK	.46 (11.5%)	PCK	.69 (13.8%)
TK	.4 (10%)	TPK	.69 (13.8%)
TCK	.4 (10%)	TK	.66 (13.2%)
PK	.31 (7.75%)	TCK	.66 (13.2%)
CK	.2 (5%)	CK	.59 (11.8%)

Table 5: TPACK Self-Reflection Comparison of 2019 and 2015 GenCyber Camp Result

Despite an overall increase in participants' average scores on the TPACK Self-Assessment Survey, data analysis did not provide any insights into why 12 (34%) teachers' TPACK knowledge decreased after the weeklong camp. This finding is further complicated by the fact that all the teachers participating in the previous GenCyber Camp scored as well or higher on the post-test than on the pre-test. Similarly, the average change for composite scores for the 2019 group increased from pre- to post-test by 3.17 points (7.2%), which demonstrates a notable decrease in this area from the 4.76 (8.7%) average increase demonstrated by the previous GenCyber teachers. Similarly, the average score on the pre-test was 28.8 (65.5%) and average score at post was 31.97 (72.7), out of 44 possible points, compared to the 2015 teachers' scores on the pretest which averaged 34 (61.8%) and 42 (76.4%), out of 55 possible points, respectively. Overall, the results from the TPACK Self-Awareness survey were positive. However, a closer look at the data in comparison with other GenCyber camps suggests the need for further research to explore the effectiveness of pedagogies employed at future cybersecurity camps.

Conclusion

GenCyber Camps provide in-service teachers with the knowledge and skills necessary to incorporate GenCyber Principles and Cybersecurity Concepts into their curriculum. Findings from pre- and post-camp TPACK surveys indicated growth in the majority of participants' knowledge and confidence for integrating technologies, but these findings also generated several unanswered questions: Why did some participants' scores drop on pre- to post-camp surveys? Why did participants in this camp score lower on pre-/post-surveys than those of participants in a previous GenCyber camp? To answer these questions, further research is needed to explore the effectiveness and impact of pedagogies employed at future cybersecurity camps.

Considering the limitations of the study, it is notable that camp instructors were not familiar with TPACK or the TPACK Development Model. Future research could examine the impact of this training on participating in-service teachers' TPACK. The instrument selected is an adapted version of an assessment which focused on mathematics-specific content and aligned to a mathematics TPACK development model. It is worth considering repeating this study using tools or instruments which are designed and validated specifically for cyber and programming focused content. Finally, while the population of this study was small, GenCyber camps are offered across the country each year. Future research should be conducted on the impact of GenCyber camps on in-service teachers' TPACK at camps in other states and regions of the country. Results from these studies could prompt the GenCyber Program, which is aligned with the model developed by Shulman and Shulman, to adopt the TPACK framework as part of their evaluations process.

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Appendix A

TPACK Self-Reflection Survey

The chart below asks you to consider specific domains of knowledge from the TPACK Model on page

1. Please consider each of the areas below and rate your current confidence with regard to each area. Place a checkmark to indicate your confidence level. Please provide additional, explanatory comments, as appropriate.

	I feel very confident in this area. I am a leader and a resource for other teachers.	I am fairly confident, but I am still seeking additional resources for improvement.	I am a novice in this area, and I have a great need to improve my knowledge.	I'm not sure what this means.
CK: Content Knowledge *Knowledge of your subject area*				
PK: Pedagogical Knowledge *Knowledge of teaching strategies, techniques, integration of learning theory*				

TK: Technological Knowledge *Knowledge of technology use by students and teachers*				
TCK: Technological Content Knowledge *Knowledge of use of technology to enhance content*				
PCK: Pedagogical Content Knowledge *Knowledge of learning theory and strategies specific to subject area*				
TPK: Technological Pedagogical Knowledge *Knowledge of the integration of learning theory in technology use*				

TPACK: Technological Pedagogical Content Knowledge *Knowledge of strategies to use technology and appropriate teaching strategies to teach content*				

Comments:

Appendix B

TPACK Self-Assessment Survey

TPACK Development Model Self-Report Survey

Specific to Programming & Cyber Security (technology)

Please place a check in the box to the left of each statement that describes your beliefs and/or integration of technology in your classroom. You may give additional information in the spaces provided to clarify your selections or if none of the statements describe your beliefs/integration.

	1. I can see how this technology might be useful with some of the topics in my curriculum, but I am not convinced its use will make much of a difference for my students' learning.
	2. I believe this technology would make a difference in my students' learning and would like to use this technology with my students, but I'm not really sure how to integrate its use with the topics in my curriculum.
	3. I believe this technology is beneficial to students' learning. I have allowed my students to use this technology for investigation of a few topics.

	4. I believe this technology facilitates students' learning. I have allowed my students to use this technology for investigation of several topics. I have changed some of my lessons to integrate the technology and am searching for more ways to integrate the technology into the curriculum.
	5. I am convinced that this technology is essential to promote learning for my students. My students use this technology on a regular basis. I extend the objectives in my curriculum by allowing my students the opportunities to develop deeper content understandings through the technology use.
Use this space for any additional information related to the statements above.	
	6. I don't like to allow my students to use this technology on tests because I want to know what they know about the content/discipline, not what the technology can do.
	7. I allow my students to use this technology only on certain parts of tests or only on certain tests.
	8. If I allow my students to use this technology on tests, I make sure that the test questions measure what my students understand (concepts) along with what they know how to do (procedures).
	9. I allow my students to use this technology on tests. I make my tests to involve a variety of questions (some that require the technology, some that they could use the technology, but it is not required, and some in which the technology use has no impact).
	10. I design my assessments so that the students must demonstrate the understanding of the content/discipline through the technology use.
Use this space for any additional information related to the statements above.	
	11. I believe that if my students use this technology too often, they will not learn the content for themselves.
	12. I am afraid that if I try to introduce a new topic with this technology, that my students will be too distracted by the technology use to really learn the content. I want them to learn how to do it on

	paper first, and then they can use the technology.
	13. I have allowed my students to explore a few topics using this technology even before the topics are discussed in class.
	14. My students explore several topics for themselves using this technology to help them develop a deeper understanding. Sometimes the students' thinking guides their explorations in directions other than what I had planned.
	15. I design my own technology lessons. When I plan my lessons, I really think about how to integrate the technology to help the students better understand the content. After the lesson, I reflect on the lesson and how it could be changed to increase student understanding using this and/or other technologies.
Use this space for any additional information related to the statements above.	
	16. I might show my students how this technology relates to the topic, and I don't mind if my students use this technology outside of class, but I do not plan to allow class time for the students to use this technology.
	17. If my students use the technology to explore a new topic, they won't think about and develop the content area skills for themselves.
	18. I try to use this technology to promote my students' thinking but have not had a lot of success.
	19. I often use pre-made technology activities to engage my students in their learning. I reflect on my students' thinking, communication and ideas during the technology use to make decisions about any changes that need to be made in the design of the lesson.
	20. I cannot imagine my classes without this technology! Using this technology is a vital piece of facilitating my students' learning and helps promote their thinking to more advanced levels.
Use this space for any additional information related to the statements above.	

	21. This technology might be useful, but before I could use this technology, I would have to teach my students about the technology and how it works. I have too many objectives to cover to do that.
	22. I use this technology occasionally, such as between units or at the end of the term. The technology use doesn't necessarily tie with the content goals of the class.
	23. I use this technology to reinforce concepts that I have taught earlier or that my students should have learned in a previous class. I do not use it regularly when teaching new topics.
	24. I use this technology as a learning tool to engage my students in high-level thinking activities (such as projects or problem-solving).
	25. I use this technology to present concepts and processes in ways that are understandable to my students. I actively accept and promote use of this technology for learning. Other teachers come to me as a resource for ideas of how to help their students use the technology to promote understanding.
Use this space for any additional information related to the statements above.	
	26. My students and I use this technology for procedural purposes only.
	27. I have led my students through a few simple ideas of how to use this technology that I learned during professional development.
	28. I have led my students through uses of this technology that I learned during professional development, but I changed the activities to meet the needs of my students.
	29. When my students explore with this technology, I serve as a guide. I do not direct their every action with the technology.
	30. On a regular basis, I use a wide variety of instructional methods with this technology. I present tasks for my students to engage in both deductive and inductive strategies with the technology to investigate and think about concepts to deepen their understanding.
Use this space for any additional information related to the statements above.	

	31. In my class, the focus is on the content first. I can imagine that perhaps this technology might be used to reinforce those ideas only after the students have shown they can perform the skills on paper.
	32. I allow my students to use this technology to assist them with their skills. I direct my students step-by-step to use this technology.
	33. I use some exploration activities with this technology, but I usually guide my students through the steps to save class time.
	34. I have explored a variety of instructional methods with this technology, to allow my students to engage both inductively and deductively.
	35. I use this technology in a student-led environment, where the students explore with the technology both individually and in groups. When working in groups, all members of the group are actively involved.
Use this space for any additional information related to the statements above.	
	36. I would consider attending a workshop demonstrating the use of this technology, but only if it is local.
	37. I am interested and would be likely to attend workshops or professional developments to learn more about how to use this technology to further content area education.
	38. I am likely to attend professional developments related to technology use in content area education and to share those ideas with other teachers in my building, but I am likely to focus on learning one type of technology integration at a time.
	39. I have made contact with others who are using this technology and plan to meet and work with them throughout the year to integrate this and other technologies appropriately into our curriculum.
	40. I believe it is time to transform our curriculum to one that utilizes 21st century technologies! I have found organizations and workshops that I can attend to learn more about how to integrate this and other technologies into my curriculum. I plan to share what I learn with

	others in my district.
Use this space for any additional information related to the statements above.	
	41. My students can use this technology only after they have mastered the pencil-and-paper skills.
	42. I allow my students to use this technology on a regular basis, usually just for skill purposes and under tightly controlled circumstances.
	43. I have a few units in which I allow students to explore new topics with this technology.
	44. I encourage my students to use this technology during most class meetings. They often explore new topics using this technology.
	45. I allow my students to use this technology in every aspect of the class and encourage the technology use to challenge the boundaries of what they can learn and understand.
Use this space for any additional information related to the statements above.	
	46. My content area has not changed just because we have more technologies available. Students still need to know how to do everything they've always been taught. For example, my students can use the calculator to take square roots after they prove to me that they know how to do the algorithm to find square roots.
	47. It takes too much time and hassle to allow the use of this technology every day. I will let my students use it from time to time, maybe when we aren't so rushed to cover objectives.
	48. Using this technology will present some management issues, but I plan to integrate this technology as a tool to enhance some, but not all, of my lessons and help my students take a new approach to learning content in some units.
	49. I know that using this technology presents some new management issues, but I actively look for ways to minimize those challenges so that my students can use this technology on a regular

	basis.
	50. Using this technology presented some issues, but through extra planning and preparation, I have overcome those challenges and maximize the use of this technology resource.
Use this space for any additional information related to the statements above.	
	51. I see the use of this technology tool for simplifying some "messy" problems (problems with "unfriendly" real-life numbers for example). I make this technology available on the rare occasion that we encounter those type problems (maybe for extra credit).
	52. Using this technology allows me to demonstrate more examples.
	53. I take a different approach to teaching using this technology. Through its use, my students not only explore and apply key concepts using multiple representations, but they are also able to examine more complex topics making connections than they would be able to without the technology use.
	54. Using this technology allows my students access to explore and apply key concepts using multiple representations (such as symbols, graphs, tables, and/or data lists) and making important connections among representations and concepts.
	55. My students regularly explore and apply key concepts of more complex topics than normally outlined for this class using multiple representations and connections.
Use this space for any additional information related to the statements above.	