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A Case Study of a STEM Teacher's Development of TPACK in a Teacher Preparation Program

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Abstract: This case study involved researching pre-service secondary STEM teachers' development of TPACK by use of modeling & simulation applications. The main research question focused on how do self-reported TPACK measures align with demonstrated TPACK knowledge and skills. The study design was qualitative and included five secondary STEM pre-service teachers who were completing their program of study and teaching lessons in the field with secondary students. This particular brief paper reports on one of the pre-service STEM teachers in this study. Coding and analysis were carried out to search for characteristics of tasks that support development of TPACK in future teachers. Findings from this one case identified somewhat high marks on the TPACK self-scores but weaker identification of features of modeling and simulation (M&S) applications integrated into instructional use. The challenge for teacher education programs is to search for ways to better measure and support TPACK development in future teachers.

Introduction

With the Common Core State Standards – CCSS (National Governors Association, 2010) and Next Generation Science Standards (NGSS Lead States, 2013) movements across the United States, STEM teachers are expected to engage students in actively exploring the discipline rather than passively receiving material. Such learning experiences include making sense of problems, using reasoning and logic, manipulating appropriate tools to investigate and solve various tasks, and making specific use of modeling and simulation (M&S). These practices are to be adopted for all students, but how teachers develop such practices and incorporate them into classroom instruction is often ambiguous.

Technology as a tool for teaching and learning can help bridge the content-pedagogy divide in STEM disciplines. Tasks generated around M&S can provide rich environments for pre-service teachers to investigate STEM concepts, be original in their approach to such tasks, and offer some level of validation that technological tools can benefit learning STEM concepts in ways that are different from traditional lecture learning. The authors believe that pre-service teachers must experience M&S activities themselves before they can transfer the ideas of such learning scenarios into future instruction. ISTE (2017) professes, “Educators continually improve their practice by learning from and with others and exploring proven and promising practices that leverage technology to improve student learning” (p. 1). ISTE also promotes the idea that educators should define learning goals to explore and apply pedagogical methodologies made possibly by technology (2017). The question that arises is where do they experience such situations in teacher preparation programs and how do these experiences influence the development of TPACK? This driving question underlies a study involving pre-service teachers and the challenges in their development of TPACK.

With growing interest in TPACK across the research community, questions on how to measure this knowledge, as well as developing valid and reliable survey instruments to measure TPACK, is a major area of investigation (Abbitt, 2011; Deng, Chai, So, Qian, & Chen, 2017). Of interest to this study is Deng and colleagues (2017) research pointing out that often studies do not examine a teacher’s subject-specific TPACK associated with his/her beliefs about the subject (chemistry in this instance) and his/her teaching practices. They raise the issue that these beliefs often impact the use of technology in instruction and may be factors in one’s TPACK ratings. There also is evidence that TPACK scores may focus more on teachers’ subjective knowledge – how much they believe they know about given components of TPACK – which is tied to confidence but is not always a good indicator of ability (Drummond & Sweeney, 2017). Self-scoring is not always an accurate measure of one’s performance and understanding which muddies the water even more in the TPACK research arena.

In her study of pre-service science and mathematics teachers, Niess (2005) found that many pre-service teachers learn about technology outside the development of their content and pedagogical content knowledge bases. Use of technology is typically addressed in a more generic way that is removed from the discipline and taught by a generalist. This practice misses the mark where programs should provide opportunities to learn science and mathematics by experts in the subject matter with technology integration. This practice is slowly gaining strength in the teacher education community – especially with accreditation organizations such as CAEP (Council for the Accreditation of Educator Preparation), but the technology appears to be a moving target that education cannot keep up with. Teacher preparation programs have a responsibility to train teachers for today’s classrooms with tools that make learning meaningful as well as preparing their future students for college and workforce opportunities.

The Study

“Understanding the impact of technology on the practices and knowledge of a given discipline is critical to developing appropriate technological tools for educational purposes” (Koehler & Mishra, 2009, p. 65). Research in the measurement and development of TPACK has centered around the work of Koehler & Mishra (2009). To identify ways to measure TPACK beyond self-reporting of one’s perceptions of their own TPACK knowledge, Koehler and colleagues (2012) identified five measurement techniques including self-report, performance assessments, open-ended questionnaires, interviews, and observations. The motivation for the current study was situated in prior research indicating a mismatch between performance and self-reporting of one's TPACK knowledge (Watson & Enderson, 2018), particularly for pre-service teachers who may be honest in responding but lacking in their own knowledge of integration of materials, technologies, and instructional strategies to support learning. Thus, this research focused on addressing ways one can generate performance assessments that integrate M&S technological tools which also might provide a measure of one's TPACK development. Researchers were interested in trying to determine if there were specific characteristics that emerged in this process and if so, what impact these traits might have with respect to TPACK development. This study focused on a single research question:

> *How do pre-service teachers' TPACK self-reporting scales align with performance assessments created for secondary STEM instruction?*

Researchers collected data from the TPACK self-assessment along with performance assessments that pre-service teachers created, attempted to carry out in class instruction, and discussed in a video recording ("think-aloud") for the disciplines of secondary life sciences, biology, physics, and mathematics. These assessments required digital tools that focused on M&S applications in the STEM classroom. In addition, participants were asked to reflect on their experience in using a framework to guide their thoughts and actions in a learning scenario, creating the performance assessment, and implementing it with secondary learners. It was this reflection process where researchers hoped to target specific elements of assessments that supported TPACK development.

Framework & Methodology

Jang & Chen (2010) addressed the notion that new science teachers should be prepared with the ability to create valuable technological experiences for learners. Their work in transforming Angeli and Valanides' (2005) five criteria into written assignments for assessing TPACK was used as a framework for the current study. They developed a transformative model where integration of technology and peer coaching were used to study the TPACK of pre-service science teachers. Elements of this model, along with peer coaching and support, were adopted for this study.

This study employed a qualitative design approach with participants who were pre-service STEM teachers completing a secondary STEM teacher preparation program. Participants consisted of five undergraduate students majoring in a STEM field with a minor in teaching. All participants (4 females, 1 male) took a series of STEM education courses as part of their program of study focused on inquiry, learning and instruction, teaching styles, tools, classroom management, history, research in STEM, and meeting the needs of all learners. In these courses, pre-service teachers often explored scenarios involving interdisciplinary concepts and ideas. The program embraced the notion that pre-service teachers need support in integrating technological tools into instruction of content and thus, technology integration was incorporated across multiple STEM courses. Experts in the discipline were instructors of these courses where M&S technological tools (e.g., PhET, Shodor, Excelets) were integrated in a variety of ways.

Data collection occurred in one of the final courses of the program which is taken simultaneously with student teaching. One major data source included administration of a 22-item survey assessing participants' self-reported TPACK (Zelkowski, Gleason, Cox, & Bismarck, 2013) completed during the final four weeks of the semester. For each item, participants rated their knowledge and skills on a five-point Likert scale ranging from strongly agree (5) to strongly disagree (1). The TPACK instrument provided four subscale scores, one each for technological, pedagogical, content, and integrated TPACK knowledge. Scores were derived by calculating the mean response for all items in each scale resulting in scores that ranged from high (5) to low (1) for each subscale. In addition to participant TPACK self-assessments, "think-alouds" and performance assessments used by pre-service teachers in the field were collected and analyzed. By coding and generating themes across the TPACK scores and supporting materials, researchers identified categories or traits of assessments that may contribute to the development of TPACK for pre-service STEM teachers. In addition, TPACK self-assessment results were analyzed with the performance assessment items to look for congruency or gaps in TPACK development (or lack of). Unique participant numbers were used in coding and linking of all data to reduce bias during analysis. Pseudonyms were used to ensure confidentiality during reporting. General findings for this case study are presented with a spotlight on one pre-service teacher to illustrate the characteristics of how a performance assessment can be used to help measure TPACK while clarifying how performance scores may be used to understand the alignment or misalignment of self-reported TPACK in future work.

Findings

Overall, the findings of the case study showed that three out of the five participants (i.e., Kolbe, Shannon, and Crystal) rated themselves in a manner that was congruent with what they produced in the performance assessments for their middle/high school students to explore. Their ratings aligned with what was created for students to use, which was not always a high mark but rather a mark that was aligned with the TPACK self-reflection score and the task designed for students. In other words, in Kolbe's (pseudonym) case, he rated himself high on the TPACK measures and he also created several valuable performance tasks for his students. The same orientation was witnessed for Shannon (pseudonym), but she rated herself in a medium/neutral manner and her performance tasks were medium level and not overly engaging for student exploration. The more interesting results occurred for two of the five participants (i.e., Tamera and Jackie) where findings revealed a mismatch between the TPACK scores and the performance-based tasks they created. Their TPACK scores were reasonably good, but the products they created were quite weak in their integration of technology for student learning. For the purposes of this brief research case study, only one participant, Tamera (pseudonym), is presented. Tamera was selected due to her high self-reflection scores on all TPACK areas and the low level of instruction she created for students in her classroom.

Tamera entered the university as a biology major but decided to try out the teacher preparation track after hearing a pitch about teaching in STEM. She had never really thought about becoming a teacher but found out she liked it in an early field teaching experience. She made a great deal of growth in her teaching practices throughout the program and realized that teaching was a good fit for her career choice. Tamera classified herself as laid back, somewhat shy, and non-confrontational. She enjoyed biology but at the same time felt she needed to work hard in making sense of the content. She expressed early in the teacher preparation program she was unsure of herself in front of others but gained confidence in her teaching by early and regular field teaching experiences. The one area on the TPACK measure where she scored herself low was on the content knowledge which aligned with what she shared with researchers about studying hard to make sense of biology as a discipline.

Researchers analyzed “think aloud” videos presented by participants to outline and discuss how M&S applications were integrated into classroom instruction. Videos were viewed individually by researchers where they referenced trends in individual areas of TPACK. Specific reference to traits participants believed to be important were also noted as contributing to TPACK development. A cross check was carried out with participants to make sure what researchers heard on the “think alouds” was accurately reflected in the noted traits. Researchers found Tamera’s “think aloud” and supporting performance assessments to be quite weak in her integration of technological tools to explore STEM concepts. Characteristics of tasks were identified but were not vital to the M&S exploration presented. Tamera scored herself rather high in the TPACK survey items where her overall rating had a mean of 4.09 (out of 5). In her case, there was a bit of a mis-match between her using TPACK knowledge to develop valuable learning experiences for secondary biology students and TPACK scores from the survey. These findings are congruent to an earlier study by the authors (Watson & Enderson, 2018). In the case of Tamera, even though there were some inconsistencies on the scores and products produced, she addressed some of her own deficiencies in development of TPACK.

Details on Tamera’s performance assessment included a discussion of a learning tool for natural selection and adaptation where she actually identified some of the characteristics of M&S applications that promoted engaged student learning but was not able to incorporate them into an actual instructional exploration. Her performance assessment was not developed much more than the simulation site that was used and the observations that were to be made. There was little for students to do other than click a bird flying to see it eat moths and check the population percentage. The power of technology to facilitate learning a concept was in many ways lost in the repetitive nature (mouse clicking) of the application presented to students.

Although Tamera's performance assessment was weak, she recognized the value of having access to reliable use of technology in the classroom. She indicated that characteristics of M&S applications should include: ease in using the tool, simulating what actually would occur in real life, allowing for variation in student responses based on input, and providing connections that might impact the environment. Her overall comments addressed the challenge in having schools armed with the latest technological tools so that teachers can really use them to impact student learning and understanding.

In Tamera's case, the "think aloud" actually provided evidence of her lower level of TPACK development. From a technology point of view, she believed the M&S application she selected was a good one in that it simulated a phenomena and generated results for students. She also noted that this application was better suited to explore with technology rather than no technology and students would like it (hitting on the pedagogy). On the other hand, researchers believed that characteristics of the performance assessment she presented did not exemplify strong support for use of technology in exploring an important concept. Other study participants indicated areas that had more alignment with development of TPACK and addressed traits such as student interactions (rather than clicking the mouse), application generating more questions about the phenomena ("I wonder what would happen if . . ."), and ways to see the concept tie into other fields of study (What would this case look like for an engineer?). While these characteristics promote good teaching and understanding and the authors believe they can identify TPACK development, this was not evident in Tamera's instance. In addition, researchers found Tamera to score herself rather high on the TPACK survey items with very little confirmation on her using this level of TPACK knowledge in her development, planning, and carrying out instruction.

Conclusions

This study is important in several ways. First, it identifies that there is still more work in understanding how to develop and measure TPACK of teachers. Hofer, Grandgenett, Harris, & Swan (2011) in their research of a TPACK observation instrument, pointed out that evidence of teachers' TPACK in lesson plans and activities, as well as video recordings of instruction, provide valuable data that may support teachers' knowledge development. Researchers need to consider alternative sources to study how teachers measure on TPACK scales compared to materials and actual instruction of developed materials. These sources should provide additional understanding of how the affordances of the technology support student learning of the content and how effectively they are integrated with the proposed pedagogy. The combination of measures may also provide concurrent validity evidence for TPACK scores. Second, there is little evidence of how M&S technological tools may best fit into the TPACK measurement techniques. With more and more digital applications available on the educational market, teachers need training on how to integrate such tools into instruction to stimulate student learning and understanding. This in turn would promote a vision where teachers generate investigations steeped in content, effective pedagogy, and require technological tools to explore concepts.

This work is also important in that content experts need to promote technological tools that can be integrated into classroom instruction of specific concepts. The days of technology courses taught by generalists should be replaced by content experts who are well versed in content and pedagogy and able to seek out tools that most effectively facilitate exploring and learning concepts. Learning to teach one's subject with technology is different than learning to teach or learning about technology (Niess, 2005). Research has shown that many teachers feel under-prepared to carry out instruction using technological tools that have the potential to be powerful in classrooms. It is time for institutes of higher education to help train teachers to use instruments that will have a greater impact on the learning environment as well as align more closely with the tools scientists, technology experts, engineers, and mathematicians use in their careers.

Teacher preparation programs have an obligation to provide new teachers like Tamera with the necessary tools to do their job well. This study, and related studies, have the potential to address more specific ways that teacher preparation programs can support pre-service teachers' awareness of their strengths and limitations in developing TPACK. To support TPACK development, pre-service teachers need awareness of their own strengths and limitations, particularly in integrating more complex M&S tools in STEM. To study and develop teachers' TPACK, we need multiple methods and measures that facilitate a deeper understanding of teachers' knowledge and skills in effective TPACK integration for STEM.

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