TPACK Development in Science Teaching:

Measuring the TPACK Confidence of Inservice Science Teachers

By Charles R. Graham, Nicolette Burgoyne, Pamela Cantrell, Leigh Smith, Larry St. Clair, and Ron Harris

Knowledge related to the effective use of educational technologies has become widely recognized as an important aspect of an educator's knowledge-base for the 21st Century (ISTE, 2008; National Council for Accreditation of Teacher Education, 1997; Partnership for 21st Century Skills, 2003). Early in the history of educational technology, educators were taught in technology classes that focused primarily on technology skills independent from the pedagogical or content courses (Graham, Culatta, Pratt, & West, 2004; Hargrave & Hsu, 2000; Willis & Mehlinger, 1996). Educators soon recognized that technology skills alone did not serve them well because one could know how to operate a piece of technology without knowing how to use it effectively to promote student learning. The focus then shifted to preparing educators to integrate technology into their teaching.

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"Technology integration" became the phrase that characterized the efforts to use technology in an educational context. There have been many technology integration models or frameworks developed to help measure and guide educators in their use of technology. A few of the widely recognized frameworks include the Levels of Technology Integration (LoTI) scale (Moersch, 2002), the Apple Classrooms of Tomorrow (ACOT) continuum (Sandholtz, 1997), the North Central Regional Educational Laboratory's engage model (Lemke, 2003), and the International Society for Technology in Education (ISTE) NETS-T 2000 Standards (ISTE, 2000). For the most part, the technology integration frameworks have focused on the use of technology from a generalist's perspective; they characterize the use of technology in general pedagogical terms, independent of any particular content domain.

Most recently there is recognition among many educational technologists that the pedagogical uses of technology are strongly influenced by the content domains in which they are situated. For example, the teacher knowledge required to effectively integrate technology in a science classroom may be very different from that required for a social studies classroom. In 2006 a framework was proposed that combined three important aspects of teacher knowledge: Pedagogical Knowledge, Content Knowledge, and Technology Knowledge (Koehler & Mishra, 2008; Mishra & Koehler, 2006). This new framework (represented by the Venn diagram in Figure 1) was called Technological Pedagogical Content Knowledge (TPCK or TPACK) (Thompson & Mishra, 2007) and built upon Lee Shulman's widely cited Pedagogical Content Knowledge (PCK) framework (Shulman, 1986a, 1986b, 1987).

The TPACK framework proposes seven distinct categories of teacher knowledge. However, for the purposes of this paper, only the four categories found within the Technology circle (darker gray) of the diagram shown in Figure 1 will be considered. The Technological Knowledge (TK) represents the technical skills that were the early focus of educational technology courses (e.g., how to operate tools like word processing, spreadsheet, and presentation programs). The

Technological Pedagogical Knowledge (TPK) represents the integration of technology with general pedagogical strategies characterized by much of the "technology integration" literature (e.g., how to manage a technology-rich classroom, engage students with technology-oriented activities, and create useful presentations, assessments). The TCK represents knowledge of technology tools and representations that are used by practitioners within a content discipline (e.g., use of data collection and analysis tools like digital probes and spreadsheets by scientists). Finally, TPACK, which is at the center of the model, represents the use of technology to support content-specific pedagogical strategies (e.g., the use of technology to support science inquiry in the classroom).

With the introduction of the TPACK framework of teacher knowledge, it is important to develop ways to measure TPACK in specific content domains. *The Handbook of Technological Pedagogical Content Knowledge for Educators* has begun the task of trying to characterize TPACK in each of the major content domains (AACTE, 2008). The purpose of this research is twofold:

1. To contribute to the understanding of how to identify and measure TPACK related to science instruction.
2. To assess the change in TPACK confidence for participants in the SciencePlus professional development program.

PCK and TPACK in Science

There is a wealth of research related to Pedagogical Content Knowledge (PCK) in the domain of science (Gess-Newsome & Lederman, 2002; Magnusson, Krajcik, & Borko, 2002). While there are many different conceptualizations of PCK, two key elements across different models are a) a knowledge of strategies and representations for teaching particular topics, and b) a knowledge of students' understanding, conceptions, and misconceptions of these topics (Lee, Brown, Luft, & Roehrig, 2007; van Driel, Verloop, & Vos, 1998).

TPACK is an extension of PCK and is primarily achieved when a teacher knows a) how technological tools transform pedagogical strategies and content representations for teaching particular topics, and b) how technology tools and representations impact a student's understanding of these topics. Many science education researchers have done research related to technology and science education without explicitly using TPACK as an organizing framework; Novak and Krajick (2004) provide a good example of this with their explanation of how technology and the pedagogical strategy of science inquiry can be combined. Some researchers have started

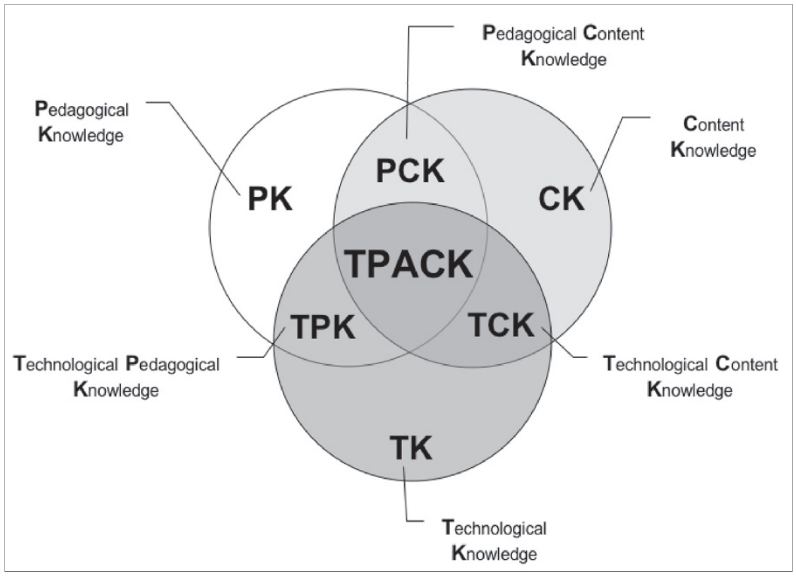

Figure 1. Visual representation of the TPACK framework.

with the idea of technology-enhanced PCK in science and moved towards using TPACK as an organizing framework for their research (Angeli, 2004; Angeli & Valanides, 2009; Valanides & Angel, 2005). Other researchers have begun to use TPACK as a framework for looking at qualitative cases of preservice and inservice science teachers and how they integrate technology with their teaching methods (Guzey & Roehrig, 2009; Niess, 2005).

In the recently published *Handbook of Technological Pedagogical Content Knowledge for Educators*, McCrory (2008) identifies ways scientists and science educators use technology to transform science content as well as their pedagogical practices. A sample of these include:

1. Speeding up time via simulations of natural events (e.g., geological animations)
2. Saving time through data collection devices and/or recording data that would otherwise be hard to gather (e.g., digital probes)
3. Seeing things that could not otherwise be seen (e.g., digital microscopes)
4. Organizing data that would otherwise be hard to organize (e.g., spreadsheets, graphical visualization models)

Technological Pedagogical Knowledge (TPK) is an extension of general pedagogical knowledge (PK). Teachers who have this kind of knowledge understand the impact that technology has on general pedagogical practices that are not content-specific. Examples of TPK might include a teacher who knows how to manage learning in a classroom with one-to-one laptops for the students, or a teacher who knows principles for developing digital presentations that are developmentally appropriate for the level of learners in the classroom.

TPACK in Science Survey Questions

"Rate how confident you are in your current ability to complete each of the following tasks"

Scale: 1=Not confident at all, 2=slightly confident, 3=somewhat confident, 4=fairly confident, 5=quite confident, 6=completely confident. TCK items only had a 0=I don't know about this kind of technology

Technological Pedagogical Content Knowledge (TPACK)

TPCK1. Find and use online animations that effectively demonstrate a specific scientific principle.

TPCK2. Use the Internet to discover common learner misconceptions related to a science topic.

TPCK3. Use digital technologies to facilitate scientific inquiry in the classroom.

TPCK4. Use digital technologies that facilitate topic-specific science activities in the classroom.

TPCK5. Help students use digital technologies to collect scientific data.

TPCK6. Help students use digital technologies to organize and identify patterns in scientific data.

TPCK7. Help students use digital technologies that extend their ability to observe scientific phenomenon.

TPCK8. Help students use digital technologies that allow them to create and/or manipulate models of scientific phenomenon.

Technological Pedagogical Knowledge (TPK)

TPK1. Use digital technologies to improve my teaching productivity.

TPK2. Use digital technologies to improve communication with students.

TPK3. Effectively manage a technology-rich classroom.

TPK4. Use digital technologies to motivate learners.

TPK5. Use digital technologies to improve the presentation of information to learners.

TPK6. Use digital technologies to actively engage students in learning.

TPK7. Use digital technologies to help in assessing student learning.

Table 1: TPACK in Science Survey Questions:

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Technological Content Knowledge (TCK)

TCK1. Use digital technologies that allow scientists to observe things that would otherwise be difficult to observe.

TCK2. Use digital technologies that allow scientists to speed up or slow down the representation of natural events.

TCK3. Use digital technologies that allow scientists to create and manipulate models of scientific phenomenon.

TCK4. Use digital technologies that allow scientists to record data that would otherwise be difficult to gather.

TCK5. Use digital technologies that allow scientists to organize and see patterns in their data that would otherwise be hard to see.

Technological Knowledge (TK)

TK1. Save an image from a website to the hard drive of your computer.

TK2. Search the web to find current information on a topic that you need.

TK3. Send an email with an attachment.

TK4. Create a basic presentation using PowerPoint or a similar program.

TK5. Create a document with text and graphics in a word processing program.

TK6. Learn a new program on your own.

TK7. Install a new program that you would like to use.

TK8. Take and edit a digital photograph.

TK9. Create and edit a video clip.

TK10. Use Web 2.0 technologies (e.g., blogs, social networking, podcasts, etc.).

TK11. Create your own website.

Finally, Technological Content Knowledge (TCK) is an extension of content knowledge (CK). Both CK and TCK are examples of desired student knowledge as well as teacher knowledge. TCK in science represents knowledge of the technologies and representations that are relevant to functioning within a scientific domain: the technological knowledge that a scientist would have and that educators want young student-scientists to acquire. Examples of this kind of knowledge might include how to use technology to collect and analyze data, or how to use technology to model and understand difficult relationships in scientific data.

Method

Context

This pilot study involved fifteen inservice teachers who participated in the *SciencePlus* professional development program through Brigham Young University in 2008. *SciencePlus* (http://scienceplus.byu.edu/) is an intensive professional development experience that focuses simultaneously on science inquiry pedagogy (a subject-specific pedagogy) and biology/earth science content knowledge. Teacher participants are involved in three phases of instruction with science educators and university scientists:

1. Learning phase – Two days of interactive classroom instruction on science content topics, science process skills, and full science inquiry.
2. Enacting phase – Six days of in-depth study of group-selected science topics and enactment of full science inquiry in field locations (Great Basin or Zion National Park).
3. Transfer phase – Developing, teaching, and reflecting on two inquiry lessons that participants implement in their own classrooms.

Participants were given a digital microscope (QX5) and taught how to use it in their classrooms as part of the program. They were introduced to other technologies including a range of geology animations, GPS devices, digital cameras, Google Earth, and digital microscopes. Participants also used a range of technologies as a way to record, analyze, and present data from their inquiry projects.

Participants

Eleven of the fifteen participants were elementary education teachers (10 females and 1 male); four were secondary education teachers (1 female and 3 males). Participants' classroom teaching experience ranged from 1 to 26 years. All teachers had access to the Internet and at least one computer and projector in their classrooms. Two of the participants had access to digital probeware for use in their classrooms. In general, participants began the program being quite confident in their ability to use basic productivity software like MS PowerPoint and MS Word. They began with less confidence in their ability to produce media-rich materials or use science-specific technologies. All participants chose to participate in *SciencePlus* in order to improve their science teaching by learning to engage their students in science inquiry activities.

Survey

For this study we developed a pre-post questionnaire to measure inservice teachers' confidence related to the four TPACK constructs that involve technology—TK, TPK, TCK, and TPACK. The survey also included two open-ended questions:

1. How do you currently use digital technologies to support your science teaching?
2. If you had access to any digital technologies you wanted for use in teaching science, briefly describe what technologies you would use and how you would use them.

Table 1 on the two previous pages displays the thirty-one items used for the four TPACK constructs. TK items represent a range of basic to intermediate technology skills that might be relevant to a teacher. TPK items represent several common ways of using technology in teaching that apply across all content domains. The TPK items represent the use of technology to support general pedagogical strategies as opposed to content-specific pedagogical strategies.

For the development of the TCK items we leaned heavily on McCrory's (2008) characteristics or affordances of technology tools that make them useful for scientists. The TCK items were intended to get at the teachers knowledge of different genres of "tools of the trade" that are used by scientists. The TPACK items were designed to represent teachers content-specific use of technology in the classroom including a) the use of tools created specifically for science education, and b) the use of scientists "tools of the trade" in their teaching (e.g., TCK applied in a teaching context). Measurement scales for all questions were: 1=Not confident at all, 2=slightly confident, 3=somewhat confident, 4=fairly confident, 5=quite confident, 6=completely confident. Additionally, all TCK items included a "0=I don't know about this kind of technology" as part of the scale. Cronbach's alpha was calculated to determine internal consistency reliability for the constructs using the combined pre- and post-data with the following results: α(TPACK) = 0.951, α(TCK) = 0.913, α(TPK) = 0.971, α(TK) = 0.922.

Descriptive statistics for all items on the pre- and post-survey as well as mean increase (Post- subtract Pre-) for each item.

	Pre-survey Results		Post-survey Results		Post – Pre
	Mean	SD	Mean	SD	Mean
TPACK1	3.93	1.53	4.47	1.36	0.54
TPACK2	3.67	1.29	4.60	1.18	0.93
TPACK3	3.27	1.62	4.40	1.18	1.13
TPACK4	3.33	1.35	4.40	1.24	1.07
TPACK5	3.20	1.47	4.00	1.13	0.80
TPACK6	2.87	1.69	4.07	1.10	1.20
TPACK7	2.67	1.59	4.47	1.06	1.80
TPACK8	2.53	1.73	3.60	0.91	1.07
Ave	**3.18**		**4.25**		**1.07**
TPK1	3.47	1.69	4.60	1.06	1.13
TPK2	3.73	1.44	4.67	1.29	0.94
TPK3	3.53	1.41	4.27	1.34	0.74
TPK4	3.67	1.68	4.53	1.13	0.86
TPK5	3.80	1.78	4.80	0.86	1.00
TPK6	3.53	1.81	4.60	1.18	1.07
TPK7	3.33	1.54	4.47	1.25	1.14
Ave	**3.58**		**4.56**		**0.98**
TCK1	2.13	1.85	4.40	1.18	2.27
TCK2	1.80	1.97	3.07	1.39	1.27
TCK3	1.73	1.98	2.80	1.52	1.07
TCK4	1.73	1.98	3.53	1.41	1.80
TCK5	2.00	1.89	3.60	1.55	1.60
Ave	**1.88**		**3.48**		**1.60**
TK1	5.33	1.11	5.80	0.56	0.47
TK2	5.33	0.90	5.67	0.49	0.34
TK3	5.73	0.59	5.93	0.26	0.20
TK4	5.33	0.90	5.73	0.59	0.40
TK5	5.53	0.92	5.93	0.26	0.40
TK6	4.40	1.18	5.07	0.96	0.67
TK7	4.67	1.40	5.47	0.64	0.80
TK8	4.47	1.41	5.20	0.86	0.73
TK9	3.20	1.90	4.27	1.53	1.07
TK10	3.40	2.03	4.27	1.44	0.87
TK11	3.20	1.47	3.60	1.45	0.40
Ave	**4.60**		**5.18**		**0.58**

Table 2: Descriptive statistics for all items on the pre- and post-survey as well as mean increase (Post- subtract Pre-) for each item.

Because of the small number of participants in the research, we knew we would not be able to establish construct validity using item analysis techniques. However, content validity for the survey items comes from their basis on definitions and descriptions in the TPACK and PCK literature. The wording for each of the survey items as well as descriptive statistics at the item level and the construct level is reported in the findings so that the reader may determine an individual comfort level with the findings.

Findings

Confidence Questions

The majority of the survey questions were measures of participant confidence related to four TPACK constructs. For each of the survey items we calculated descriptive statistics including means and standard deviations (see Table 2 on the next page). We also calculated mean values for the constructs (TPACK, TPK, TCK, and TK). For each student, we calculated the difference between their post- and pre-survey scores. We used a paired-samples t-test to determine the likelihood that pre-post differences at the construct level were not due to chance.

There was significant improvement between pre and post scores on all of the TPACK constructs (see Figure 2 on the next page). For the paired-samples t-test, results indicate a significant increase for all constructs (see Table 3 on the following page). Effect sizes included in Table 3 were calculated for all significant results and are in a generalized form as the ratio of the difference between the group means divided by the estimated standard deviation of the population (Cohen, 1988). (According to Cohen, effect sizes of approximately .20 are considered to be small, while .50 are moderate and .80 or above are large.)

Additionally, on the pre-survey, 20% of the participants responded that they were not even aware of the kind of technology represented by items TCK1 and TCK5, and 33% responded similarly for items TCK2, TCK3, and TCK4. On the post-survey, no participants indicated they had no awareness of the technologies represented in the TCK items.

Open-ended Questions

The first open-ended question (How do you currently use digital technologies to support your science teaching?) was coded to identify evidence of *general* versus *content-specific* uses of technology. Within each of these two categories we also coded for whether it was an example of *student use* of technology or *instructor*

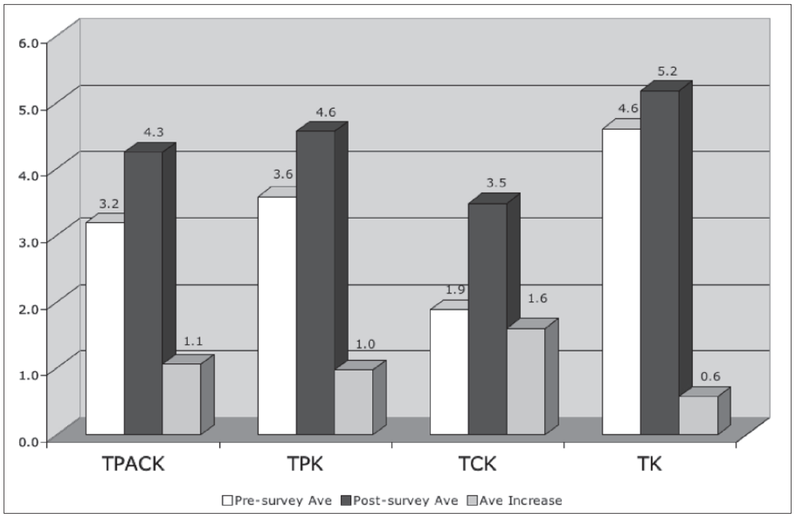

Figure 2. Average participant pre-survey, post-survey, and increase in science-related TPACK confidence (n=15).

use of technology. This gave us four total coding categories: content-specific/instructor use, content-specific/student use, general/instructor use, and general/student use. Two researchers independently coded the pre- and post-surveys with an inter-rater reliability of 84% on each one. The researchers came to consensus on how to code the instances where there were coding differences. The majority of the differences were related to ambiguity regarding whether students or the instructor were the primary users of the technology. Table 4 on the following page provides examples from the data for each of the four codes.

Table 5 on the following page shows the number of participants who had at least one code in the four categories in the pre- and post-surveys. There was an increase in reported technology use in all categories from the pre- to the post-survey. While only 7/15 (47%) of participants reported some kind of content-specific use of technology on the pre-survey, 14/15 (93%) of participants reported content-specific uses of technology on the post-survey. The greatest increase was in the category of content-specific/instructor use of technology. This may have been because, as part of the program, participants were given a digital microscope that many took into their classrooms and began using in their teaching.

Discussion

Data from the survey indicate that the participants began and ended with the greatest level of confidence in their TK, followed by TPK, then TPACK, and finally TCK (see Figure 2). This finding reinforces the idea that confidence in TK is foundational to developing confidence in the other three forms of knowledge measured. This makes sense if one believes that some basic technical awareness and skills are a prerequisite to being able to meaningfully integrate technology into teaching. It also was not surprising that TPK scores were the second highest since this kind of knowledge has often been taught both in preservice and inservice trainings. It was interesting, however, that TCK knowledge was significantly lower than all of the other constructs. Initially, we speculated that this might be because the TCK scale included a zero value for "I don't know about this kind of technology," while the scales for all other constructs ranged from 1 to 6. But even if all of the values that were initially coded by the participants as "0= I don't know about this kind of technology" were converted to "1=not confident at all" the mean score on the pre TCK construct would be 2.2—still significantly lower than all other scores, including the TPACK score.

McCrory (2008, p. 197) writes about three classifications of technologies that can be used in the science classroom: 1) technology unrelated to science that can be used in the service of science (e.g., word processors, spreadsheets,

Results of Paired-samples t-tests for Factors of Technological Pedagogical Content Knowledge

Factor	N	M	SD	t	*p*	ES
Pre TPACK	15	3.18	1.37	3.70	.002*	.84
Post TPACK	15	4.25	0.94			
Pre TPK	15	3.57	1.51	4.21	.001*	.67
Post TPK	15	4.57	1.03			
Pre TCK	15	1.88	1.88	3.28	.005*	.85
Post TCK	15	3.48	1.21			
Pre TK	15	4.60	1.05	2.64	.019*	.55
Post TK	15	5.18	0.49			

*Significant at the .05 level.

Table 3: Results of paired-samples t-tests for factors of Technological Pedagogical Content Knowledge.

Examples of General Activities (TPK) and Content-specific Activities (TPACK) that use technology, coded from question:

"How do you currently use digital technologies to support your science teaching?"

General Activities **Instructor Use of Technology** **Examples**	 **Student Use of Technology** **Examples**
• Using PPT for presentation (TPK5) • Using projection equipment to show videos (TPK5) • Using internet to find resources (TPK1) "I have used many different PowerPoints." "I occasionally show PPT in the classroom. I have also used the internet to access information." "Sometimes I use an EIKI projector to show something from a book so everyone can see." "I use an Interwrite tablet to navigate the internet."	• Students use PPT to create presentations (TPK6) • Student research on the internet (TPK6) • Audience response system (TPK6, TPK7) • Online testing (TPK7) "The students are learning to make their own PowerPoints as a form of presenting." "We recently purchased a system called Turning Technologies where students can take tests on an overhead using remote clickers." "We have some assignments where the students use the internet to research different topics or complete worksheets."
Content-Specific Activities **Instructor Use of Technology** **Examples**	 **Student Use of Technology** **Examples**
• Science animations and interactive content (TPCK1) • Using online resources with topic-specific content for activities (TPCK4) "I have access to a projector and like using it to show educational websites, animations, powerpoints, and video clips for my science unit. I found a great website (similar to google earth) where you can zoom in on the cracks in the earth's crust and the different tectonics plates. I also found an animation that shows the breakup of Pangea." "I show video clips to demonstrate principles we are talking about." "We also use an interactive volcano website during our landforms unit." "I use a document camera to show them things. "The digital camera allows me to take geology related pictures to show my students."	• Use of digital data collection/ observation tools like probes and scales (TPCK5) • Use of digital microscopes to extend students ability to observe phenomenon. (TPCK7) "I use the digital microscope to observe bugs and discuss living and non-living things in an environment." "We have these amazing tools called 'LabQuest' that are handheld computer devices. They have probes that can measure temperature, pH, heart rate, speed, and many other things." "We use the digital microscope to look at things individually and all together." "I like to provide them with digital microscopes to see organisms or digital thermometers to track and chart temperature change."

Table 4: Examples of General Activities (TPK) and Content-specific Activities (TPACK) that use technology, coded from question "How do you currently use digital technologies to support your science teaching?"

Number (and percentage) of participants with responses coded in four categories for question

"How do you currently use digital technologies to support your science teaching?"

	General/ Instructor Use	General/ Student Use	Content-specific/ Instructor Use	Content-specific/ Student Use
Pre-survey	7 (47%)	6 (40%)	6 (40%)	2 (13%)
Post-survey	12 (80%)	8 (53%)	12 (80%)	4 (27%)

Table 5: Number (and percentage) of participants with responses coded in four categories for question "How do you currently use digital technologies to support your science teaching?"

graphic software), 2) technology designed specifically for teaching and learning science (e.g., simulations, animations), and 3) technology designed to do science (e.g., probes, digital microscopes). While all three categories might contribute to an instructor's TPACK knowledge, technologies in McCrory's third classification are the technologies most related to TCK knowledge. The fact that TCK scores were so much lower than TPACK scores might indicate that participants felt more comfortable in their ability to use technologies designed for *teaching* science (McCrory's #2) than technologies designed for *doing* science (McCrory's #3). If so, this trend might be explained by the greater number of elementary teachers than secondary teachers who participated in the study. Historically, elementary teachers have little experience doing science, limited science content knowledge (CK), and low science self-efficacy (Gess-Newsome, 1999; Raizen & Michelsohn, 1994). These characteristics may explain why elementary teachers would feel more comfortable with technologies designed for teaching science over those designed for actually doing science.

Another important observation that came from the analysis of responses to the open-ended questions was that more of the participants used technology with general pedagogical strategies than with content-specific pedagogical strategies (see Table 5). Additionally, in both the general- and content-specific categories, participants were more inclined to use pedagogical strategies in which the instructor, not the students, was using the technology. The data did not indicate the underlying reason(s) for the trends. It may be that limited technology in the classroom makes instructor demonstrations and presentations the only practical technology option. It could also be that the teachers are more comfortable with a teacher-centered approach to teaching because of the modeling and preparation they have received.

Conclusions

In this study we piloted an instrument for measuring confidence levels in four of the seven TPACK knowledge constructs: TPACK, TPK, TCK, and TK. The instrument was useful in helping *SciencePlus* program coordinators to see significant increase in the TPACK confidence of participants over the eight-month duration of the program. Analysis of the data also helped program coordinators recognize that more could be done to help classroom teachers develop TCK confidence by doing more to help them learn about content-specific technologies that are used in *doing* science.

Additionally, while a major focus of the program is science inquiry (a student-centered pedagogy), many of the participants did not get technological tools into the hands of their students when implementing inquiry in their classrooms; rather, the participants were the primary users of technology in the classroom. This knowledge should lead to a greater focus during the next session on practical ways to enhance inquiry in the classroom through the use of technology. Finally, a next logical step in the research would be to move beyond measuring participant's increase in TPACK confidence to developing TPACK performance assessments in an attempt to directly measure the TPACK constructs.

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