

A Letter from the Guest Editor

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Educational practice is in constant need of improvement. It is not that refinements in practice will be accomplished day-to-day or year-to-year, but over time we must systematically change our pedagogy so that we continue to prepare our students to fully engage in a changing economy and evolving society. As we enter a new economy, which is technology-and innovation-oriented, and demands the use of 21st-century skills, we must develop a 21st-century pedagogy that is student centered, project based, and integrates technology. This does not mean that we cease teaching content. Students will still need to understand the concept of slope, and they will still need to be able write a coherent text that has a topic, a thesis, supporting ideas, and a conclusion. How they learn content and skills must also prepare them to work in the new economy. The case study conducted by Paul Morsink and his colleagues and the response by Shabbi Luthra, published in this Special Section, gives us insights into how we can address these great challenges.

In their mixed method study of a 7-month professional development program to help elementary teachers learn to integrate their knowledge of technology, content, and pedagogy, Morsink et al. demonstrate the importance of balancing intensive instruction with systematic support *over time* to help teachers develop a deeper sense of competence using this integrated approach. From my perspective, one of the most significant findings of this study is the case of an initially reluctant learner who, over time, came to realize the value of integrating technology into his teaching and his classroom. This growth may not have been accomplished if he had just taken a summer institute in technology without subsequent coaching and inquiry about his practice and attitude. As the authors suggest, the predisposition to integrate technology is a precursor to doing it well. As such, this case says as much about

the success of the intervention as about those participants who developed a sophisticated ability to integrate technology with subject matter and pedagogy.

As Shabbi Luthra points out, the study builds on previous work that has revealed the importance of using technology to facilitate a student-centered, project-based curriculum. She reminds us that previous research has shown that there is a trajectory to learning how to effectively integrate technology into one's pedagogy that goes beyond a simple introduction to a type of technology. Rather, real learning comes through using the technology in a supportive environment, and receiving both feedback on one's performance and guided opportunities to try again until one is able to use the technique independently. Although this may sound obvious, it is not how we generally approach professional development for teachers.

In addition to providing a valuable model for how to integrate technology with content and pedagogy, the case study and commentary point to the vital importance of creating systematic and sustained approaches to the professional development of teachers if we expect them to master the techniques. In addition to intensive instruction at the beginning of the learning cycle, teachers are best served if they also receive ongoing and focused support as they use the new techniques throughout the academic year. This suggests that we may want to identify one approach we want a group of teachers to learn (e.g., technology or literacy across the curriculum) and provide focused support over time until the technique is mastered. The articles in this Special Section suggest that this is a more promising approach than introducing a new technique at the next professional development opportunity and providing no guidance during the challenging task of classroom implementation.

Professional Development to Support TPACK Technology Integration: The Initial Learning Trajectories of Thirteen Fifth- and Sixth-Grade Educators

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ABSTRACT

This study examined the initial learning trajectories of 13 upper elementary teachers as they developed technological, pedagogical, and content knowledge (TPACK) while participating in a 7-month professional development program focused on integrating technology into their classroom practice. The program was collaborative and non-prescriptive: teachers worked on self-chosen summer projects with flexible support from a university-based partner. A descriptive multicase study design was employed to track teachers' learning progressions. Data included interviews, surveys, digital artifacts, and researchers' notes and memos. During the program, teachers developed varying degrees of TPACK. Analyses distilled six initial TPACK learning trajectories.

The U.S. Department of Education's 2010 National Educational Technology Plan notes "widespread agreement that teachers, by and large, are not well prepared to use technology in their practice" (p. 39). This fact may seem counterintuitive, given that in-school access to computers, the Internet, and other digital technologies (e.g., digital cameras, digital projectors) has grown steadily over the past 20 years (National Center for Education Statistics, 2010a, 2010b). Further, more teachers than ever before have received some professional development (PD) on a technology-related topic (Darling Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009; Partnership for 21st Century Skills, 2009). In addition, many of the nation's youngest teachers are "digital natives" (Prensky, 2001) whose lives have been infused with digital technologies almost from birth. Why, then, are so many teachers still not well prepared to infuse technology into their curriculum and instructional practices?

One likely reason is that integrating technology into curriculum and instruction entails much more than knowing how to operate a computer or use a piece of software. Teachers may acquire a high level of expertise in these areas and still fail to integrate technology into their practice—or fail to do so effectively. As Mishra and Koehler (2006) have argued, effective instructional use of technology requires weaving together three essential strands of teacher knowledge—technological knowledge, pedagogical

knowledge, and content knowledge—guided at every step by the goal of enhancing student learning. To this end, technological knowledge is necessary but not sufficient. What matters more is a teacher's ability to engage in the kind of flexible, adaptive bricolage with new technologies that is required for effective pedagogy and to meet students' particular learning needs. Yet a growing body of theory and empirical research (e.g., Chai, Koh, & Tsai, 2010; Doering, Veletsianos, Scharber, & Miller, 2009; Graham et al., 2009; Guzey & Roehrig, 2009; Koehler, Mishra, & Yahya, 2007; Kramarski & Michalsky, 2009; Richardson, 2009) suggests that this bricoleur ability is multifaceted and complex—and develops only gradually, through ongoing practice and growing experience (Mouza, 2009).

No surprise, then, that the National Educational Technology Plan identifies "episodic" models of PD (where teachers receive a crash course in the use of a particular technology or technology-enhanced instructional method) as a problem contributing to the general failure to "support and develop educators' identities as fluent users of advanced technology" (p. 45; see also Borko, 2004). The report asserts that preparing a nation of tech-savvy teachers will require long-term, collaborative professional learning frameworks that unite communities of professionals and that are grounded in teachers' daily practice. This view is supported by a wide body of research indicating the value of teacher training that is embedded in schools and classrooms, sustained over an extended period of time, and includes both project-based activities and opportunities for reflection (Burbank & Kauchak, 2003; Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamagushi, & Gallagher, 2007; Putnam & Borko, 2000; Schrum, 1999; Wilson & Berne, 1999).

Mindful of this research and the importance of teachers developing both technology expertise and flexible and adaptive technology integration expertise, we designed a professional development institute for teachers at TreeTop Elementary (a pseudonym) that was long-term, project-based, non-prescriptive, collaborative, and grounded in their arena of practice. The structure was purposely flexible to serve teachers' evolving goals and priorities for technology integration. The project was sustained over a 7-month period and included multiple and diverse points of contact between the university research team and the school professionals.

Although several studies have investigated the impact of teacher training aimed at developing teachers' ability to integrate technology (e.g., Chai et al., 2010; Doering et al., 2009; Graham et al., 2009; Guzey & Roehrig, 2009; Koehler et al., 2007; Kramarski & Michalsky, 2009; Richardson, 2009), little is known about teachers' day-to-day experiences and perceptions as they participate in training and acquire new knowledge and skills. Do these experiences and perceptions follow particular patterns? Over time, as in-service teachers move from novice to expert technology integrators in the course of an extended period of PD learning, what learning trajectories do they travel? This study was designed to shed light on this important and largely neglected dimension of technology integration in schools (for an exception, see Mouza, 2009). Together with our participant collaborators at TreeTop Elementary, we decided to put teachers' learning experiences center stage. For this reason, we report the general findings of the study and then present six profiles of teachers with contrasting learning trajectories.

THEORETICAL FRAMEWORK

The design of the professional development institute and the research investigation were informed by three complementary theoretical perspectives: the situative perspective of learning, learning progressions theory, and TPACK.

Situative Perspective

The situative perspective (Greeno, 2003; Lave & Wenger, 1991) contrasts with more narrow cognitive perspectives in that learning is seen as occurring through processes of enculturation as much as through processes of knowledge construction (Cobb, 1994; Cobb & Bowers, 1999). Enculturation refers to processes by which the ability to participate and act meaningfully in particular socially organized activities is developed in particular contexts. The acquisition of decontextualized knowledge is, by itself, not sufficient to bring about learning. Rather, learning has occurred only when the individual is able to apply new knowledge in targeted social arenas and activities. For our purposes, the situative perspective provides a framework for research that casts a wide net over sociocultural as well as cognitive processes and dynamics, grounding our focus on (a) individual teachers as learners (and their individual "learning trajectories") and (b) their evolving participation in one or more professional learning communities (Putnam & Borko, 2000).

Learning Progressions Perspectives

This project is also grounded in a conceptualization of learning progressions as complex, strategic, non-linear processes that develop over time through protracted engagement with a set of ideas (Shavelson, 2009). This view is informed by theories of change in strategy selection (e.g., Kuhn, 1995; Siegler, 1996, 2007). Kuhn and Pease (2010) note that individuals have "a repertory of strategies that they bring to a new situation, some more adequate or advanced than others" (p. 135), and that as learners

repeatedly engage with a problem, they begin to apply more effective strategies. Their movement toward expertise is unpredictable and, as Siegler (1996) has noted, their progression of strategy application looks much like a series of "overlapping waves" (p. 89) with several strategies competing, emerging, and receding over time until more adaptive strategies become the most frequently used options.

In the context of professional development, we have adopted the concepts of learning progressions and overlapping waves to conceptualize the variable paths that teachers take from novice to expert technology integrators. Importantly, however, we recognize this as a career-long process of development, composed of sub-components that can be examined closely. We identify learning trajectories as segments of this overarching, career-long progression of learning. Over time, in aggregate, trajectories will together constitute the arc of a learning progression. However, we do not assume that, at any given point in time, individual trajectories are necessarily congruent with, or predictive of, the overarching progression that may eventually emerge—especially during the initial phase of learning a new skill when variability is likely.

TPACK Perspective

With regard to teachers' learning about technology, we relied heavily on the TPACK framework articulated by Mishra and Koehler (2006, 2008). TPACK, Technological, Pedagogical, and Content Knowledge, is a framework for understanding the relationship between teachers' knowledge of technology, content knowledge, and knowledge about teaching. The framework builds on Shulman's (1986) model of pedagogical-content knowledge and adds technological knowledge as a core realm of essential teacher knowledge. Echoing Shulman's emphasis on the area of overlap between content and pedagogy, TPACK highlights the areas of overlap between content, pedagogy, and technology (Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2008, 2009; Mishra & Koehler, 2006, 2008, 2009) and asserts that effective teaching with technology happens only in these areas of overlap that are optimally integrated. The TPACK perspective strongly rejects conceptions of technology integration that focus on teachers developing expertise in isolated technologies. Instead it advocates developing a mindset that is flexible, adaptive, and committed to orchestrating the best possible fit among the three components.

Key features of this TPACK teacher mindset include:

- openness to the possibility that the content and procedures of yesterday might be improved tomorrow with the help of new technologies;
- ongoing professional reflection and a commitment to identify areas for innovation and improvement;
- a willingness to apply new methods and strategies;
- a critical stance toward novelty and innovation for their own sake;
- a critical awareness that all technologies have affordances as well as constraints;

- a critical awareness that the affordances and constraints of a given technology will likely vary over time in relation to changing purposes, contexts, and audiences;
- an ongoing commitment to maximize the affordances and minimize the constraints of technologies; and
- an ongoing commitment to learn more about technology tools and options and to access the technology expertise and advice of peers and others.

In the present study, we looked for evidence of an emerging TPACK mindset in our TreeTop colleagues.

THE STUDY

The Justification

Several studies have investigated the impact of various forms of TPACK-oriented professional development on teachers' emerging mindsets in different educational contexts (e.g., Chai et al., 2010; Doering et al., 2009; Graham et al., 2009; Guzey & Roehrig, 2009; Koehler et al., 2007; Kramarski & Michalsky, 2009; Richardson, 2009). However, little is known about the texture of teachers' day-to-day learning experiences with technology and how these unfold over time. Specifically, to our knowledge no study has examined in depth, and over an extended period, in-service teachers' idiosyncratic learning trajectories as they experienced them and reported their reactions, nor have we identified studies incorporating teachers' responses to researchers' analyses of their learning trajectories, as is the case here.

The Research Questions

Koehler et al. (2007) assert that TPACK development is a "multigenerational process" (p. 758) and that developing deeper understandings of the "complex web of relationships between content, pedagogy and technology and the contexts in which they function" (p. 758) requires protracted engagement with TPACK ideas. We wondered what this multigenerational process (i.e., learning progression) might be for teachers in the same school with different levels of technological, pedagogical, and content knowledge who were explicitly engaging with the ideas of TPACK for the first time.

This study was therefore designed to answer the following research questions:

1. What initial learning trajectories do upper elementary teachers move through as they develop expertise for integrating technology into their curriculum and teaching?
2. What influences and experiences shape these learning trajectories?

The Method

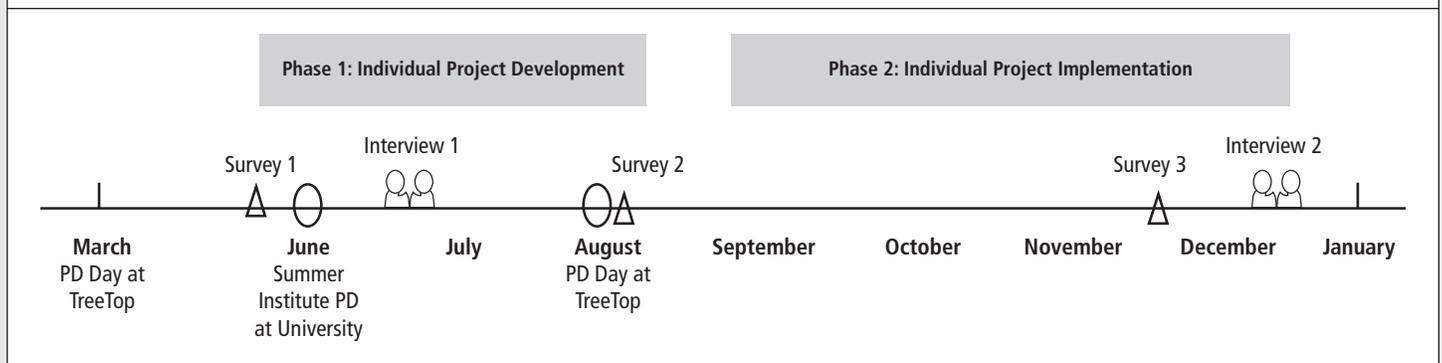
School and Professional Development Context. TreeTop Elementary is located in a rural public school district in a Midwestern state. The district covers roughly 150 square miles and serves 2,000 students. It has a strategic plan for technology integration that is updated every three years. Since 1995, the district has had a fiber optic Local Area Network connecting it to the Internet.

TreeTop Elementary serves approximately 360 students in grades 5 and 6. Each of three computer labs is equipped with 30 desktop computers, and there is a smaller library lab with nine computers. Each classroom has a LCD projector, an ELMO document camera, and at least one computer. Effective use of technology is viewed as a desirable part of instruction.

The professional development and research team from Michigan State University was initially invited in March 2010 to provide a day-long seminar on digital tools. Following the seminar, a Summer Institute was developed as an extension of this seminar. The Institute involved a subset of the original seminar participants who were then paired with members of the university research team. This pairing allowed researchers to provide individualized, intensive, and specific support for the practitioners as they developed individual projects for implementation in the fall. In addition to ongoing and as-needed interactions between the teachers and researchers via e-mail and video conferencing, the Institute met for two days, once in June and again at the end of the summer in August. Figure 1 provides the timeline of the professional development.

The first Summer Institute session was structured to link teachers' open-ended exploration of new technologies with targeted thinking about curriculum planning for the fall semester.

Figure 1. Timeline of professional development institute. Triangles indicate survey administrations, circles indicate day-long professional development sessions as part of the Summer Institute, and interviews are indicated with the "two-people" icon. Note that Phase 1 began in June and lasted until August and that Phase 2 began in September and ended in December.



Teachers were given a brief orientation to the TPACK framework, with particular emphasis on the idea that all tools have affordances and constraints and the corollary idea that any decision to use a particular technology will inevitably have implications for both curriculum and pedagogy. The teachers were partnered with the university team to engage in open-ended conversations about their curricular and pedagogical goals and the technologies that might serve them. Each teacher filled out a planning chart—housed in a single shared Google Doc that all teachers and administrators could access—briefly describing his/her idea for a summer learning project. The teachers and their university partners arranged virtual meeting times throughout the summer for follow-up conversations regarding the projects. After this first session, each teacher's learning regarding technology and integration focused on his/her particular project goals.

The second session in August was structured to allow teachers to share the work of the summer and discuss options for technology integration across the curriculum with their grade-level planning teams.

Participants. Thirteen practitioners voluntarily participated in the Institute. The group included ten full-time classroom teachers, the principal, the counselor and health teacher, and the literacy coach. The professional development team included one professor of teacher education and educational technology and six education doctoral students from the university (all of whom have taught at the K–12 or post-secondary levels).

Data Collection Procedures. Figure 1 summarizes the data collection timeline. The practitioners completed three electronic surveys via SurveyMonkey: a) in June 2010, before the first Summer Institute PD session; b) in late August, immediately following the second summer institute session; and c) in December 2010 after teachers had implemented their personal projects during the fall semester. (To obtain a copy of the full survey, please contact the first author.) Practitioners also completed two interviews (June 2010 and December 2010), which were conducted and recorded by their paired research team member via Skype. Researchers also documented e-mail correspondence, Skype calls, and other communications.

Data Analysis Procedures. Primary data analysis involved statistical analysis of survey responses and examination of patterns that emerged. Repeated measures Analysis of Variance (ANOVA) was used to compare responses across the three survey times. The ANOVA results were used to identify typical and non-typical response trajectories of the practitioners over the course of the Summer Institute. Secondary data analysis involved transcribing and analyzing interviews and sifting through answers to open-ended survey questions, correspondence, and researcher notes and memos. Based on the ANOVA results, these data sources were analyzed with a view to identifying and describing the influences and experiences that shaped teachers' learning trajectories.

RESULTS

Primary Data Analysis

The mean scores for each Likert-type question were compared across the three survey iterations using repeated measures ANOVA. Statistically significant main effects were observed for Question 2 (Knowledge of Technology in General), $F(2, 11) = 7.314$, $p = .003$, Question 3 (Knowledge/Expertise of Tech Integration), $F(2, 11) = 22.966$, $p < .001$ and Question 7 (Priority of Tech Integration), $F(2, 11) = 8.927$, $p = .001$, indicating that in these areas there was significant change in teachers' views from June to December. Subsequent post hoc tests with the Bonferroni correction were run for additional insight into the direction of change in the three areas. These results indicated the following: a) overall, the teachers' self-rated general knowledge of technology improved over the duration of the institute, but the most growth was perceived to occur between June and August; b) teachers similarly perceived significant growth in their knowledge and expertise for technology integration between June and August, but did not, in general, perceive growth in this area between August and December; and c) teachers significantly increased their prioritization of technology integration between June and August, but by December, prioritization had essentially returned to pre-PD institute levels.

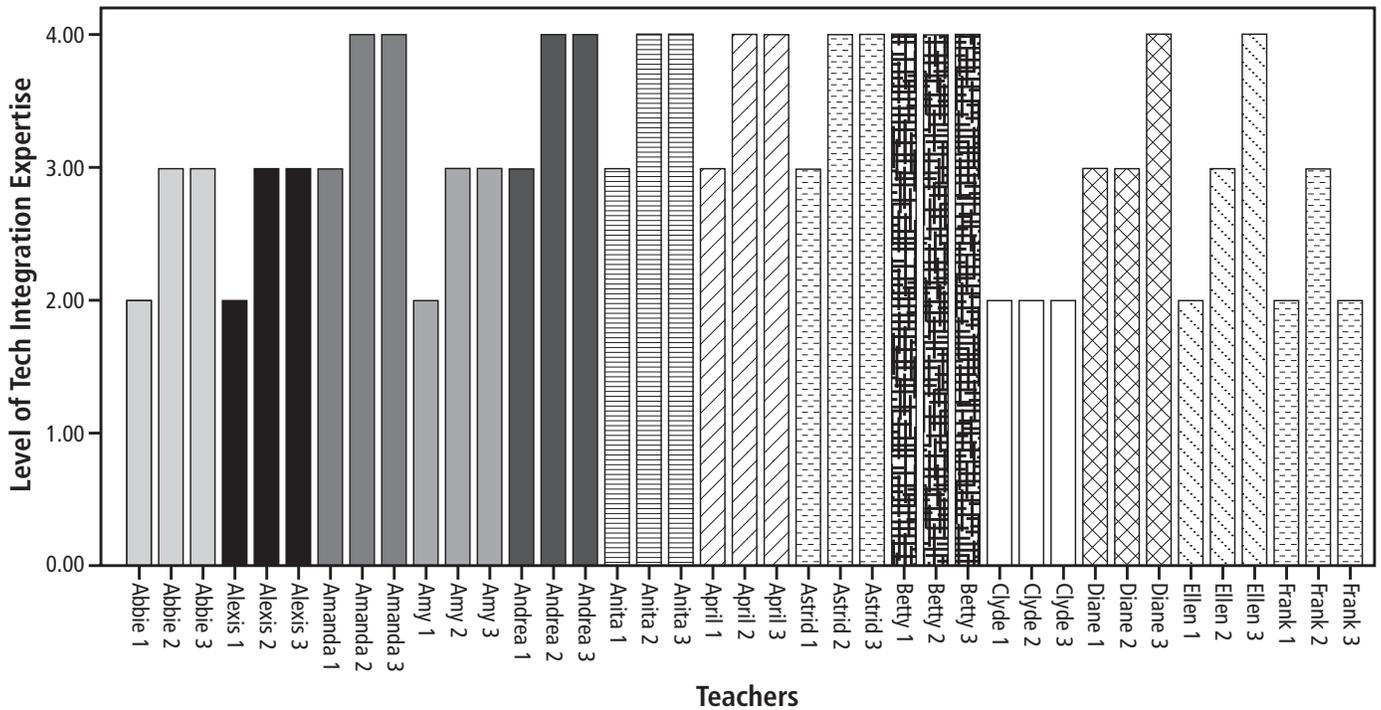
Secondary Data Analysis

The third survey question that focused on current level of knowledge and expertise of technology integration was intended to gauge change in teachers' perceptions of TPACK expertise over time. Although it was not the only variable to have changed in a statistically significant way over the course of the Institute, this variable was of greatest import to the theoretical framework of this study. More than "general knowledge" or "prioritization of technology integration," teachers' self-reported knowledge and expertise for technology integration is a central indicator of the TPACK mindset. For this reason we chose to base our descriptions of initial TPACK learning trajectories on the results from this question alone.

In response to our first research question, we identified six distinct trajectories (see Figure 2). These identified trajectories were then fleshed out into descriptive profiles with data drawn from interview transcripts, e-mails, researcher memos, and responses to other survey questions. During this phase we also identified data relevant to our second research question and incorporated these data into each profile. The following section presents the resulting trajectory profiles.

Overview: Initial TPACK Learning Trajectories. The most common trajectory was for the teachers to rate themselves at the same level on Survey 3 as on Survey 2. This trajectory, "Climb, Plateau" (C-P), was demonstrated by eight of thirteen teachers in their answers to Question #3 (see Figure 2). Five additional trajectories were also observed with regard to self-ratings on levels of knowledge and expertise; we present a series of profiles to describe these cases.

Figure 2. Teachers’ self-ratings of tech integration knowledge and expertise. Bars filled with various grayscales represent the Climb-Plateau trajectory. Other trajectories are represented with patterned shading. Labels 1, 2, 3 indicate survey iterations. “Abbie 1,” for example, is Abbie’s self-rating on the first survey (in June); “Abbie 2” is her self-rating on the second survey (in August); and “Abbie 3” is her self-rating on the third survey (in December).



- “Start High, Plateau” (SH-P): “above average” on all 3 administrations of the survey (n = 1);
- “Start Low, Plateau” (SL-P): “minimal” on all 3 administrations of the survey (n = 1);
- “Plateau, Climb” (P-C): “moderate” in Spring and Summer and “above average” in late Fall (n = 1);
- “Climb, Climb” (C-C): “minimal,” then “moderate,” then “above average” on each successive administration of the survey (n = 1); and
- “Climb, Decline” (C-D): “minimal” in late Spring, “moderate” in Summer, and “minimal” in late Fall (n = 1).

Table 1 identifies participants by a first name, position, grade level, and subject(s) taught, and provides the topics of all the summer institute projects. Participants are grouped by learning trajectory. All first names are pseudonyms.

Each case represents a type of learning trajectory with evidence of the experiences and influences that shaped them. The profile ends with a short conclusion as well as a participant commentary on the accuracy of the researchers’ analyses.

CASE: COMPOSITE LEARNING TRAJECTORY

Composite Learning Trajectory Profile #1: Climb, Plateau

The “Climb, Plateau” (C-P) trajectory corresponds to a first period of perceived growth in knowledge and proficiency with technology integration (June to August) followed by a second period (August to December) without apparent growth—or, at least, with growth deemed insufficient by C-P teachers to merit a higher self-rating on Survey 3.

On Survey 1, many C-P teachers described themselves as lacking in technological knowledge (TK). When asked to list possible reasons not to integrate technology, the teachers’ open-ended responses included comments about knowing less than some students about technology and not feeling confident about selecting websites and using Web-based tools. At the same time, they expressed the wish not to deprive their students of potentially engaging lessons and opportunities for learning. Administrators used similar language to characterize the TreeTop climate before

Table 1. Summary of Participants by Learning Trajectory, Teaching Assignment, and Summer Project

TreeTop Staff (Name and Title)	Grade Level and Subject(s)	Summer Project
Climb, Plateau Profile (C-P)		
Abbie, Teacher	6th grade Language Arts	PBworks wiki for spelling, grammar, and composition instruction
Alexis, Teacher	5th grade All subjects except Science	Kidblog for grammar, writing, novel study; Google Docs for writing instruction
Amanda, Teacher	6th grade Language Arts	Goodreads for book clubs; Google Docs for writing instruction
Amy, Teacher	6th grade Mathematics	Student moviemaking with Camtasia to showcase "real life math"
Andrea, Teacher	6th grade Science and Social Studies	Moodle for all subject area materials and tests
Anita, Teacher	6th grade Mathematics	PBworks wiki for math skills instruction
April, Teacher	5th grade Language Arts and Social Studies	PBworks wiki for genre writing instruction
Astrid, Principal	All grades	Videos for parent communication; Google Docs for teacher planning and assessment
Start High, Plateau Profile (SH-P)		
Betty, Administrator/Literacy Coach	All grades	Exploring literacy-relevant Web tools for her own use and that of teacher colleagues
Start Low, Plateau Profile (SL-P)		
Clyde, Teacher	5th grade Mathematics and Science	Diigo to annotate websites for math and science
Plateau, Climb Profile (P-C)		
Diane, Teacher/Counselor	All grades Health	Counselor Web page design using district content management system
Climb, Climb Profile (C-C)		
Ellen, Teacher	5th grade Language Arts	Moodle for quizzes on vocabulary, literary terms, and grammar
Climb, Decline Profile (C-D)		
Frank, Teacher	6th grade Science and Social Studies	PBworks wiki to document lessons for absent students

the Summer Institute: staff was described as "curious" and "nervous." The principal also pointed out that, at the outset of the PD, she and her staff "didn't know what [they] didn't know."

Phase 1: June to August. Between Surveys 1 and 2, C-P teachers made strides in TK. They researched the platform or tool(s) they had chosen for their summer projects; explored the affordances of these tools; and set up necessary infrastructure. Much of this work was done solo. However, the typical C-P teacher called on her university partner for technical support, suggestions for alternative platforms and tools, feedback on the work, or a boost in morale.

These contacts took the form of e-mails and short Skype calls. During this early stage, the typical C-P teacher reported valuing her partner's just-in-time support and ability to serve both as guinea pig for, and expert reviewer of, her project work.

With regard to technological-pedagogical knowledge (TPK), over the summer these teachers focused mainly on planning and assembling. Given the summer break and the fact that they had not yet implemented their new technology, attention and energy were focused mostly on TK and Content Knowledge (CK). The primary pedagogical concern for many took the form of envisioning the logistics of classroom implementation, including securing

computer lab space and developing lab-specific class management and workflow procedures.

With regard to technology-content knowledge (TCK), C-P teachers' insecurities regarding technology appeared to be counterbalanced by confidence in curricular knowledge, which served as a safe base camp for their explorations of technologies. One C-P teacher, April, commented:

I'm real familiar with the curriculum. I mean, that [part has been] kind of been easy for me in learning the technologies. . . . Whenever I learn a new technique, new technology, I'm always thinking of how the curriculum can be involved in that and it just kind of comes naturally just because I've been involved in curriculum so long.

Exploring new technologies in support of specific curricular projects tied to familiar curriculum also appeared to strengthen C-P teachers' TPACK mindset for achieving a tight fit between technology, curriculum and pedagogy. This mindset shift is reflected in the survey data. For example, respondents were asked whether concern for the fit between technology and teaching style and between technology and curriculum would be *not important*, *somewhat important*, *important*, *very important*, or *decisively important*. Their responses indicated that, as their technology integration knowledge and expertise increased from Survey #1 to Survey #2, they placed greater importance on achieving a tighter fit between technology and content and between technology and teaching style.

At the end of Phase 1, C-P teachers reported growth in their knowledge and expertise in integrating technology into their curriculum and teaching. Teachers were focused on developing specific projects, and they brought their curricular and teaching expertise to bear on the exploration and mobilization of new technologies. They were appreciative of one-to-one support from university learning partners, and prioritized more highly the alignment and "fit" of technology with content and teaching style.

Phase 2: August to December. In fall 2010, seven of eight teachers implemented the projects they had worked on during the summer, and several teachers implemented other technology-enhanced lesson plans and projects. During this implementation phase, most C-P teachers experienced both successes and challenges. On Survey 3, C-P teachers' reported that their knowledge and expertise for technology integration had remained the same since August.

In the fall, many C-P teachers continued to advance their own TK beyond what was necessary for their summer projects. An important catalyst was the decision by administrators to obtain a Google Apps for Education account for the school, which instantly gave every teacher and student easy access to a suite of Web tools, and many teachers devoted time to exploring these tools. The flip side of this increase in TK for many teachers was a saturation point. By fall, they had accumulated a wealth of resources, and the challenges of implementation seemed to shift the focus from exploring and planning to troubleshooting and monitoring. Rather than striving for additional knowledge or expertise, many

reported a need to take stock of how their attempts at integration had played out.

With regard to TPK and TCK, in the fall, many C-P teachers reported receiving support and encouragement from their colleagues. Beyond the August PD session, where teachers shared their projects with their colleagues, peer collaboration appeared to increase and continue throughout Phase 2.

In weekly grade-level meetings, teachers discussed with their colleagues their ongoing ups and downs with technology integration. These conversations served as a source of practical help and advice and promoted a general awareness of the importance of flexibility and versatility—a key tenet of a TPACK mindset. From Survey #1 to Survey #3, on average, the eight teachers' assessments of their colleagues' suggestions and support in meeting their learning needs increased in value from between *moderately helpful* and *often helpful*, to between *often helpful* and *most helpful*.

C-P teachers' August-to-December comments regarding their ability to successfully integrate technology, in the main, shifted from general apprehension about things not working to more specific concerns, directly connected to experiences and issues of implementation. A teacher who, in June, reported feeling generally nervous, in November reported challenges associated with lab hardware not working and with managing pedagogical objectives when software applications were slow.

Computer lab use was up overall during Phase 2. All C-P teachers reported spending more time there in fall 2010 than they had during the previous semester, resulting in some challenges. The principal noted that the increase in teacher interest had led to the need for greater computer lab availability; she reported her attempts to secure laptop computers for each team.

Conclusion. By the end of Phase 2, teachers were able to describe in more specific terms the realities and challenges of technology integration, thus demonstrating a fuller knowledge-in-practice than in August, even if they continued to rate themselves at the same level of knowledge and expertise. While a plateau may seem to indicate stasis, the data suggest that the gains in enthusiasm and confidence from Survey 1 to Survey 2 were supplemented by gains in knowledge-in-practice from Survey 2 to Survey 3. These data are consistent with the characterization of learning progressions as the result of repeated attempts at implementation (Siegler, 1996) within a context of adaptation and evaluation (Mishra & Koehler, 2008).

Practitioner comments. After reading the above description of the C-P trajectory (in rough draft form), several C-P teachers commented that it accurately captured the most important aspects of their experience.

"Climb, Plateau" teachers offered additional hypotheses regarding the possibility that teachers may, in the future, climb again after a period of implementing new technology because they will feel increasingly motivated to seek new tools and improve their knowledge and skills.

Following are a series of profiles of teachers who exemplified a non-typical learning trajectory. The cases are presented to

inform the reader of the variability that is possible in teachers' learning trajectories.

CASES: NON-TYPICAL LEARNING TRAJECTORIES

Betty: Learning Trajectory Profile #2:

Start High, Plateau

A first non-typical learning trajectory was a "Start High, Plateau" (SH-P) where the self-rated level of knowledge and expertise regarding technology integration began "above average" and remained the same across all three surveys. Betty, the only teacher with this SH-P profile, is the literacy coach. Her self-rating appeared consistent with her mentoring role at the school, her service on state technology committees and in a number of professional organizations, and the fact that she herself has led workshops on technology integration.

In June, Betty's advanced level of technology knowledge and expertise was evidenced by the extensive list of hardware, software, and Web tools she was currently using for both teacher work and student instruction. The hardware included the ELMO document camera, digital projector, Flip camera, digital camera, and iPod, in addition to laptop and desktop computers. Her software and Web tools included Wikispaces, Jing, Delicious, YouTube/TeacherTube, Skyward, Weebly, Ning, Wordle, GoogleDocs, Movie Maker, Skype, and Elluminate Live! During the June PD day she used Twitter to post 140-character Tweets for colleagues at other schools to read online.

Also in June, Betty's thinking about technology integration showed a TPACK-type concern for always connecting technology with content and pedagogy. For example, in response to a question about factors that would influence her decision-making about integrating technology, Betty listed six, including whether the technology would "showcase the specific curricular concept(s) that I would like to address" and "anticipating plausible challenges that students and/or I may face while learning through this medium."

Over the summer months and into the fall, Betty scouted for new digital tools she could use with her students and share with her colleagues. By December, she reported having used the following software and Web tools for the first time: Google Calendar, Data for Student Success, Camtasia, VoiceThread, Prezi, iCal, PhotoPeach, Keynote, Glogster, Screen Toaster, iMovie, GarageBand for Podcasting, iDVD, WordPress, Stop Motion Freeware, and Wimba.

The qualitative data did not suggest change from Phase 1 to Phase 2 of the PD, as was the case for the majority of her colleagues. Instead, there was sustained activity around technology learning and integration as Betty remained focused on finding the "goodness of fit" between a given technology and student-learning goals—whether it concerned her own students or those of a colleague. For example, Betty talked on more than one occasion about "the content I'm attempting to bring into focus through technology." This idea of technology bringing particular concepts "into focus" (while presumably leaving others out of focus) builds

on the idea of technology having both affordances and constraints, with the teacher balancing the trade-offs.

Betty's thinking during the entire PD period was marked by high level of reflection and problem solving. For example, Betty asked: "What scaffolding and/or modeling can I do to make this easier for students? [. . . W]ould it help to make a ScreenToaster [screen-capture] video how-to, set up a demo project, bookmark websites, etc.?" With her colleagues in mind, she also reflected on the particular affordances and constraints of teaching with technology in the school's two computer labs, stating at one point that the labs' seating arrangement (with computers anchored to tables in rows) did not allow students to work in groups in contrast to her office that was furnished with a large round table and wireless laptops.

Interestingly, Betty rated the following factors as "unimportant to consider when integrating technology": "My opinion about the fit between technology & my teaching style" and "What I've done before." These ratings seem to suggest that Betty prioritized considerations of content and curriculum over her past pedagogical habits and predilections. In other words, she saw herself and her pedagogical choices as highly flexible and adaptable.

Conclusion. Betty's role as literacy coach positioned her to be in the vanguard of technology integration efforts and to be engaged in thinking about curricular and instructional implications of technology integration at a high level, for herself and her colleagues. She started the PD with an advanced TPACK mindset focused on thoughtfully weaving together technology, pedagogy, and content. Throughout the PD period she deepened and applied her TPACK mindset in new and varied ways, for herself and her colleagues.

Practitioner comments. After reading this description, Betty commented on the overall accuracy. With regard to the extended plateau period in her trajectory, she expressed agreement with "the idea that a plateau in one's trajectory did not seem to indicate a time of no learning." She further explained that: "[TreeTop's] adoption of Google Apps for Education [in September 2010] opened the floodgate to learning (Google Docs, Prezi, VoiceThread, Glogster) . . . but encouraged me to slow down and work and learn beside our students in this new digital space." This was a time when she "needed to slow down and go deep." She noted "conversations with colleagues and hard knock experience" as sources of her "deepening sense, over time, of the complexities of technology integration." Betty concluded by saying, "the more you learn about something, the more you realize how much MORE there is to unearth, discover, question, and wonder about."

Clyde: Learning Trajectory Profile #3:

Start Low, Plateau

In contrast to the "Start High, Plateau" profile, Clyde showed a "Start Low, Plateau" trajectory (SL-P). At each survey, Clyde consistently reported that his knowledge and expertise regarding technology integration were "minimal." He also reported "minimal" knowledge of technology in general and "minimal" ability to help colleagues with technology problems. He said, "When I sit in

on meetings and listen to things the other teachers are doing, it's like I don't even know what [they're] talking about."

In Phase 1, Clyde set a goal to learn more about Diigo, a free social bookmarking and research tool (Diigo Inc., 2010). Over the summer, however, he did "very little with it" because competing responsibilities left little time to work with technology. On Survey 1, he listed "not having the technology or time" as the most significant obstacles to integrating technology into his teaching. He also emphasized time pressures during his interview.

I definitely should be doing more and I've done very little, actually, with all the other things I get involved with. [Every day] is pretty full until late at night and then just keeping up with the normal paper work. I blame that, I don't know if that's a good excuse or not? [. . .] We have to, you know, keep track of so many different sets of data.

He acknowledged a feeling of culpability, however, and indicated that more time to explore technology would make a difference for him.

It's my fault. I know the only way that's going to change is if I could just start sitting down and change how much time I dedicate from what my other jobs are and start just doing more of that. I know that's how they [my colleagues] figured it out.

And yet, he admitted that it was hard to commit when he was not feeling confident. On Surveys 1 and 2, Clyde noted technology integration in the lower half of his priorities. He explained his lack of motivation:

I get real nervous working at it [technology]. I get into something and then I'm always either getting myself lost or I don't know what to do next and it just gets frustrating. To me, it's more work.

In Phases 1 and 2, Clyde did not demonstrate any observable, substantive improvement in his TK or TPK, but in December, at the end of Phase 2, there was evidence that his understanding of technology integration, and of himself as a technology integrator, had changed.

When asked to list the factors that would influence his decision-making about integrating technology, Clyde's first two survey responses focused on access to technology, state curriculum expectations, and unspecified "students' needs." His third survey responses, however, were striking in their inclusion of the pronoun "I": "Could I find interesting sites for the subjects?" "Would I have access to a larger lab when I need it?" "Would the site work when I need it?" Even his last factor, "Would all my students be able to see the displays?" specifically names *his* students, as though he were no longer imagining students in general, but rather thinking concretely about the logistics of his own students' experiences in his classroom during a technology-enriched lesson. Importantly, Clyde listed technology integration as ranking in the top half of his priorities on Survey 3.

In terms of TPACK mindset, Clyde seemed to have moved to a place of greater openness. While lacking in confidence and aware of his limitations with technology, he was not resistant to change. He indicated a desire to do more and yet, still seemed blocked, perhaps because he viewed technology integration as a problem of overwhelming proportions that would require a great deal of his attention. At the end of Phase 2, he said:

For me to stay in this field [. . .] I have to start getting trained or getting myself comfortable with the idea [. . .] I definitely know I've got to do that. As soon as I can get a summer, or some weekends or whatever, I definitely have to get some classes and some time with some people that can help me start navigating myself through some of this stuff and not feel so nervous about it.

Conclusion. Clyde made progress toward a TPACK mindset of openness but he finished the PD institute without making substantive gains in TK, TCK, or TPK. In terms of learning progressions, it may be that before any real development on TPACK can occur, teachers must come to see themselves as technology integrators and adopt not just a mindset of openness, but also a long-term view that frames technology integration as an iterative process of small steps rather than a singular commitment of major time and effort.

Practitioner comments. Clyde commented that this profile accurately, "captured the fact that I've spent very little time keeping up with new technology and computer software." He added, "Unfortunately [the profile] didn't leave out or miss anything about my abilities when it comes to using technology."

Diane: Learning Trajectory Profile #4: Plateau, Climb

TreeTop's counselor and health teacher exemplified a "Plateau, Climb" (P-C) trajectory. In June 2010, Diane felt that she had a "moderate" understanding of technologies and how she could use them in her work. When asked in the first interview about her reason for her self-evaluation, she replied, "I hadn't actually used Moodle or any advanced technologies." She reported student use and enjoyment as her primary drivers for learning more about technology. Diane was experienced at using e-mail and messaging software, but had not created content or delved into other tools.

Her university partner noted that Diane was concerned about how she might integrate technology into her work as a counselor. She worried that she might not have the same pedagogical or content-based reasons to use technologies as her colleagues. Diane chose to create a "Counselor Corner" Web page on the school's site that included her contact information, information for parents, and links to county-level health and service organizations. Using the district's content management system to construct the page, she successfully posted her information.

On Surveys 1 and 2, and during her first interview, Diane expressed a consistent, moderate level of comfort with using digital technologies. "I'm fairly savvy in using the computer," she reported in her first interview, "but probably not as much as I would like to be."

With the start of the school year, Diane became the school's health teacher. Her growth in TK and TPK appeared to have developed at a pace tied closely to her professional needs. This new part of her job prompted Diane to explore additional technologies. She began to look for online resources to use with her health students, mainly for medical information. Diane also began to use Google Docs to support her reporting tasks and took time to work with individual students who were diffident about using technology. In the third survey, she reported feeling an increased level of expertise in both her level of knowledge and her ability to use technological tools. Where previously she had been somewhat tentative about her own skills and knowledge, Diane displayed a new confidence with the tasks she had chosen.

In her reflections on the August-to-December implementation phase, Diane reported a marked increase in her comfort level with the use of technologies. During her second interview, she continued to regard her ability to share her skills with colleagues as "moderate" but proudly shared her skills with one set of applications: "If I had to pick out one thing that I think that I can do really well," she reported, "that's with the Google Docs."

Conclusion. Relative to her colleagues, Diane initially took a more measured view of technology integration in her work. As time passed and she gained experience with new tools and uncovered new reasons to incorporate them, her skills and comfort with technology increased.

Practitioner comments. After reading her profile, Diane said, "This profile is really accurate in how it portrays me. It captures that I am learning as I go and getting more comfortable all the time. I would not hesitate to try something new."

Ellen: Learning Trajectory Profile #5: Climb, Climb

Ellen's "Climb, Climb" (C-C) trajectory was the fifth type we observed. She initially presented herself as having "minimal" knowledge and expertise regarding technology integration; in December, she rated her knowledge and expertise as "above average." Ellen made steady and sustained progress with planning and developing her summer project and then, in the fall, with implementing it. She did not appear to experience significant setbacks or frustrations during this phase—the kinds of setbacks and frustrations that may have caused her "Climb, Plateau" colleagues to rate their knowledge and expertise as unchanged from August to December.

In Phase 1, between May and August, Ellen chose to create a course site for her ELA classes in Moodle (an open-source course management platform) with a collection of online quizzes focusing on grammar, vocabulary, and literary terms. Through exploratory discussions with her university partner, she identified several benefits that online quizzes could offer—ranging from the option of automated scoring to providing students with immediate on-screen feedback and suggestions for further study.

Over the summer, Ellen tackled this project in piecemeal fashion. Ellen's learning was shaped by the affordances and constraints of her chosen technology. Given the inherent step-by-step nature

of quiz creation in Moodle, Ellen's project was more linear and structured than it might have been had she decided to create content using a wiki or class website. At the same time, Ellen approached her learning with a mindset of openness to play and experimentation, stating: "I just need to play around with [Moodle] a bit and try things out."

Ellen's university partner also observed that the nature of her Moodle project required her to make decisions straddling technological and pedagogical considerations, such as whether or not to configure her Moodle quizzes to give students immediate feedback. These decisions, in turn, provided a concrete context for Ellen to connect technology with her knowledge of her students (e.g., "Will my kids learn more if they see the correct answer right away or if we discuss it later?") and to think through the pedagogical ramifications of her design decisions.

During Phase 2, Ellen started using her Moodle quizzes with her students in the school's computer labs. As she did so, she developed facility with making last-minute adjustments to quizzes (to achieve the best possible "fit" between a quiz and the material she had most recently taught) and also made new discoveries. For example, Ellen found that, in her Moodle teacher account, she could, with "just a couple of clicks," obtain useful descriptive statistics about her students' performance. With these data, Ellen realized she could deepen her understanding of her students and their strengths and weaknesses. For example, knowing how much time students took to answer a given question allowed Ellen to see beyond a student's numerical score and conclude that "this student got the right answer, but she really struggled with [the question]."

In this implementation phase, Ellen also took additional steps to integrate technology. She started using her Moodle site for other purposes besides quizzes and adopted Google Docs for writing instruction and collaborative peer editing. As her technology integration activity increased, so did the frequency with which she used computers for instruction. Ellen estimated that, prior to the PD project, she used computer technology in her classroom 1 or 2 days per month; in fall 2010 the frequency increased to 3 or 4 days per month. During the same period, her use of the computer lab also increased from 5 times per semester to between 10–15 times.

Throughout the fall semester, Ellen appeared to deepen her engagement with various aspects of technology integration. Her appreciation of the complexities deepened, as evidenced by the fact that her lists of pros and cons for integrating technology more than doubled in length from June to December. On an affective level, in December Ellen reported that she felt "more comfortable" and "more confident" regarding technology integration. As well, she stated that:

I'm finding that it's kind of addicting. The more I learn, the more I'm aware of new things that I'm being exposed to, and the more I say, "Yeah, I could probably do that."

In terms of professional learning communities, Ellen saw herself as increasingly connected to a network of people and conversations involved with technology integration: "Now [this past semester]

when there's a problem, someone [at TreeTop] is able to figure it out. . . . I know who to ask for which problems." Ellen's perception was that, at TreeTop Elementary as a whole, there was significant forward momentum in fall 2010 and that her efforts were coalescing with those of other teachers around a valuable shared purpose.

Conclusion. Ellen's C-C trajectory reflects a perception of steady and sustained growth in technology integration knowledge and expertise over a seven-month period—a perception apparently not altered by the transition from summer planning to fall implementation.

Practitioner comments. After reading the preceding description of the C-C trajectory (in rough draft form), Ellen commented that it was "accurately written" and that it captured the way "her confidence [has] grown throughout the entire process." She also commented that, "the quote about technology being addicting is also accurate."

Frank: Learning Trajectory Profile #6: Climb, Decline

Frank's learning trajectory represented a "Climb, Decline" (C-D) pattern. At the beginning of the summer Frank regarded his own knowledge of technology and technology integration as "minimal" and the process of integrating technology into his curriculum and teaching as "very difficult." During the summer, he planned to develop a system using wikis and video that would give students who had been absent access to course materials outside school. However, Frank did not spend much time working on the project, mostly due to ongoing Internet access problems at his home. Despite these difficulties, by the end of Phase 1, Frank indicated that he was more motivated to work to integrate technology in his classroom, rated his knowledge of how to do so more highly, and had placed his project higher among his various priorities as a teacher. This marked the "Climb" portion of his learning trajectory: Frank became more comfortable with the idea of integrating technology into his classroom, less concerned about the basics of implementation, and more focused on how well he would be able to execute the integration and on what his students would be able to do. At Survey #3, however, Frank's learning had been undone. His responses returned to the levels he reported on Survey #1. Once again Frank estimated his knowledge regarding digital technologies and technology integration as "minimal." He again rated the process of integrating technology into curriculum and teaching as "difficult," and the importance of working to do so had fallen from the top half of his list of priorities to the bottom half.

While limited survey responses make it difficult to explain Frank's C-D's trajectory, there is some evidence to suggest that the observed decline came as a result of experiencing the practical difficulties of integrating technology into his curriculum. For example, with regard to factors to consider when integrating technology, on Surveys #1 and #2 he provided a brief list of fairly abstract and general factors (e.g., "comfort level using it," "what to do"). However, by the third survey, Frank's description of influential factors had become longer and more specific (e.g., "how to save/store/grade activity," "time to teach students the technology," "time to implement the activity"). This pattern might suggest that,

for Frank, TPACK is a comfortable concept in theory, but putting technology integration with curriculum into practice presented a practical challenge that was not surmountable at this time.

Conclusion. Frank's "Climb, Decline" trajectory seems to have been shaped by a mounting enthusiasm for technology integration and the limitations of logistical hurdles. At Survey #3, his self-rated "minimal" knowledge and expertise with technology integration seemed to be related to the technical challenges of implementation, rather than to a closed mind or lack of interest.

Practitioner comments. After reading the preceding description of the C-D trajectory in rough draft form, Frank commented that it was "pretty accurate." He said it captured the fact that "Internet issues were very frustrating last summer" and also that, despite not making progress and feeling discouraged he "did get interested [at that time] in other things that [he] had found." Regarding the implementation phase, Frank confirmed that technical difficulties caused frustration, stating: "I was getting frustrated again when it was taking so much time to complete technology-related projects with kids." Frank also clarified the sources of his summer discouragement: "I was . . . discouraged because I really didn't know what I wanted to do for my project." Further, he "got discouraged when it became evident that it wasn't going to be what [he] had envisioned."

General Analysis of Learning Trajectories and Influences That Shaped Them

In this section we examine commonalities and differences across the six profiles as a way to synthesize salient features of the learning trajectories described and the experiences and influences that shaped them.

First, it is important to note that four of six trajectories included a time of "plateau." Only two teachers reported change in technology integration expertise at every survey (viz., the "Climb, Climb" and "Climb, Decline" teachers). As detailed in the profiles, plateau did not seem to indicate a time of "no learning." Rather, times of apparent stasis were characterized by a fuller knowledge-in-practice ("Climb, Plateau" profile), change in a teacher's self-perception as a technology integrator ("Start Low, Plateau" profile), a deepening sense of the complexities of technology integration ("Start High, Plateau" profile), and a certain openness and curiosity to explore more options for technology integration ("Plateau, Climb" profile).

Across profiles, teachers' initial learning trajectories were shaped by a multitude of influences and experiences. For every profile, a large number of experiences were reported as relevant, and these experiences were of many kinds. That said, three common and salient types of experiences and influences that shaped teachers' learning trajectories were: a) development of technical knowledge, b) peer support, and c) logistical constraints.

During the PD institute, most teachers reported growth in technical knowledge and a corresponding expansion of the technologies they used between August and December. Ellen, for instance, learned the technical steps to create quiz questions in

Moodle. Diane reported, “being good at” Google Docs. Even teachers who did not report growth in technical knowledge cited experiences with technology as a salient influence in their learning trajectory. Frank, for example, who struggled with “how to save/store/grade [an] activity” and reported technical factors as barriers, nonetheless clearly engaged with technology.

Individual teachers also seemed to consistently reference the influence of colleagues in two distinct ways: a) as supportive members of their professional learning community and b) as examples against whom to compare their own skills. Clyde, for instance, reported knowing less than his colleagues about technology but attributed their successes to having spent more time “playing around”—something that he felt he needed to do. In an interview, Betty reported a healthy culture of “competition” at TreeTop where teachers were at once helping one another to learn new tools, but also feeling a need to “keep up” with one another.

Finally, several teachers reported logistical factors such as time and access to technologies as key determinants of their experiences. Frank reported that “time to teach students the technology” and “time to implement the activity” were important factors. Clyde also cited competing responsibilities and lack of time as limitations. As noted above, the typical “Climb, Plateau” teacher focused much energy on planning and assembling the necessary infrastructure for her project, including scheduling computer lab time. Further, many of the technologies that teachers implemented for student instruction required students to have their own e-mail accounts. Once TreeTop secured Gmail accounts for all students in the fall, the variety of Web-based tools that teachers used increased (e.g., Prezi, blogs, PhotoPeach, wikis).

DISCUSSION

Results indicated that, as a group, teachers at TreeTop Elementary reported a statistically significant increase in their knowledge and expertise with technology integration between the start and finish of the professional development institute. Our further analyses of individual teachers’ experiences revealed six different initial TPACK learning trajectories. Eight teachers demonstrated a “Climb, Plateau” trajectory. Other trajectories included “Start High, Plateau”; “Start Low, Plateau”; “Plateau, Climb”; “Climb, Climb”; and “Climb, Decline.” The observed variability both within each teacher’s initial TPACK profile and across the six initial TPACK learning trajectories seems consistent with theories of change in strategy selection (Kuhn & Pease, 2010; Siegler, 1996) that emphasize a long-term recursive progression toward expertise—a process that Koehler et al. (2007) have described as “multi-generational.” Though they all worked in the same school, the teachers began the professional development institute with a) different repertoires of skills, b) different attitudes about their abilities, c) different notions of themselves as technology integrators, and (d) different technology integration goals. As they planned and then implemented their technology integration projects, every teacher developed a deeper understanding of the complex interactions of technological, pedagogical and content knowledge in

their practice; every teacher did not, however, report noticing change in their TPACK expertise, nor was growth in TPACK—among those who perceived it—always incrementally linear. Indeed, only one teacher out of thirteen experienced a linear growth trajectory (“Climb, Climb”).

Results also indicated that all teachers’ initial learning trajectories were shaped by a long list of influences and experiences. As described in the preceding profiles, these ranged from the experience of discussing technology integration ideas with colleagues to coping with the realization that students may initially know more than their teacher about a particular Web tool, and from feeling reluctant to change curriculum that has worked well in the past to feeling motivated to make changes that could increase student engagement. Quite aside from any determination of their absolute or relative importance, the sheer number and diversity of these influences and experiences associated with TPACK learning is striking. They lend vivid support to a finding from a number of studies of professional development and teacher learning, namely, that developing new knowledge and skills for classroom application is a complex, multifaceted endeavor (e.g., Borko, 2004; Garet et al., 2001). Consistent with the situative perspective described in the theoretical framework, learning also appeared to be shaped at every turn by a large variety of context-specific influences, experiences, and interactions (with students, colleagues, available hardware and software, time pressures, etc.), and by the goal of participating in meaningful socially embedded activities (teaching effectively, collaborating productively with colleagues, etc.).

Finally, this study offers further support for a finding from several previous studies that developing expertise in technology integration is a time-consuming, long-term process that requires commitment and ongoing effort from teachers (Doering, Hughes, & Huffman, 2003; Hughes, Kerr, & Ooms, 2005; Sandholtz, Ringstaff, & Dwyer, 1997). At the end of 7 months, even those teachers who had objectively done the most technology integration still felt they had much to learn; none described themselves as TPACK experts.

LIMITATIONS

The first limitation pertains to our participants, who self-selected into the PD program and into the study. Therefore, the insights may not be generalizable to learning trajectories of teachers who choose not to participate in a voluntary PD program of this kind. As well, the learning trajectories described here may differ from those of teachers participating in more heavily scripted PD focused on particular hardware or software, or integrating technology in particular ways. We would also expect that teachers experiencing a prescriptive PD curriculum with a fixed schedule and uniform learning objectives for all participants might demonstrate less variety in their trajectories than we observed. Qualitative researchers suggest that when we know relatively little about a phenomenon—as is the case with teachers’ learning trajectories as they move from novice to expert technology integrators—exploring a small number of cases to provide rich description and focused analysis is more

likely to provide clearer directions for future research (e.g., Stake, 1995; Yin, 1989). So, although our sample limits the generalizability of our findings, the rich description of these teachers' experiences presents a starting place for future research.

Another limitation pertains to the important role played in PD by non-teacher factors, especially school leadership. Individual teachers are key protagonists in the PD and technology integration story; however, as Youngs & King (2002) and others have pointed out, school leadership, institutional infrastructure, technology infrastructure, financial resources, and other such factors play a decisive role, too. TreeTop Elementary represents a particular constellation of such factors. In our collective opinion, conditions at this school were in many regards ideal, comprising as they did a highly motivated and visionary leadership team, above-average technology infrastructure, and a strong culture of peer collaboration that pre-dated the PD. Educators at a school with fewer resources, less able leadership, and/or less institutional infrastructure would no doubt move through technology integration learning trajectories in different ways.

Finally, we wish to underscore that, on the basis of the data reported here, we make no claims regarding a relationship between our PD design and the learning trajectories we observed, let alone regarding the relative effectiveness of our PD design or any of its components. All thirteen educators reported benefiting from the PD program. However, no attempt was made: (a) to measure change in teachers' TPACK knowledge using a standardized assessment, (b) to gather data regarding the impact of technology integration on student learning, or (c) to compare the TPACK learning trajectories of our participants with those of other teachers at Tree-Top Elementary who did not participate in the PD over the same period. Future research should address these areas.

IMPLICATIONS FOR PRACTICE AND FUTURE RESEARCH

Mindful of the limitations outlined in the preceding section, we draw three implications from the present study with relevance to educators, PD leaders, research design, and directions for future research.

First, it seems reasonable to expect that teachers at other schools engaged in similar kinds of PD for technology integration may experience learning trajectories as diverse as the ones we observed. Consequently, PD leaders, school administrators, and teachers' themselves may benefit from explicitly preparing for this diversity. Additionally, all those involved may benefit from preparing—psychologically and logistically—for the likely experience of gradual, rather than rapid or linear growth in knowledge and expertise and for the requirement of ongoing commitment and support.

A second implication derives from our finding that an apparent "plateau" in learning may actually represent a period of meaningful learning activity, attitude shift, or peer interaction. Being mindful of this possibility may benefit PD leaders, school administrators, and teachers.

Finally, looking ahead, this study points to the need for more longitudinal research on teachers' learning progressions for technology

integration expertise. In particular, we see a need to investigate how the kinds of learning trajectories described in this study may, over time, fit within overarching, career-spanning learning progressions.

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Response to the Case Study

SHABBI LUTHRA, AMERICAN SCHOOL OF BOMBAY

The findings of the study conducted and reported by Paul Morsink and his colleagues dovetail, in many ways, with the analyses and conclusions of previous work on the integration of technology in education—in particular, Apple Classrooms of Tomorrow (ACOT), a longitudinal research investigation, and the Essential Conditions for Technology Integration (ISTE), an analysis of research and practice.

ACOT (Sandholtz, Ringstaff, & Dwyer, 1997) was a ten-year research study that began in 1985 to understand the effects on teaching and learning of the use of technology by both teachers and students. It is one of only a small handful of studies to-date that has tracked classroom technology integration over an extended period of time (other examples include Desimone, Porter, Garet, Yoon, & Birman, 2002; and Mouza, 2009). In the ACOT project, Apple provided state-of-the-art technology to 32 teachers and their students in four elementary schools and one high school. Every student had access to a desktop computer; classrooms were outfitted with printers, scanners, VCRs, software titles, and other resources. In this respect, ACOT classrooms differed significantly from those at the one elementary school where Morsink et al. conducted their research with 13 teachers. This school was equipped with one to three computers per classroom, thus requiring a trip to the computer lab on days when the lesson required every student to have access to a computer.

The findings of the ACOT study are still relevant irrespective of how technologies have evolved over the last two decades. There were two broad findings: 1) a five-stage model of evolution that teachers go through in their integration of technology, and 2) the importance of creating student-centered, constructivist learning environments for seamless integration of technology. With regard to the first finding, all the ACOT teachers went through five phases of technology integration: Entry, Adoption, Adaptation, Appropriation, and Invention. It is a natural progression of learning and of changes in classroom practice, and is supported by research on teacher thinking. The cases reported in Morsink et al. support the finding that there is a trajectory of learning and change in practice. In addition, the ACOT study indicated that a major change of the type described—from “Entry” to “Invention”—takes time and sustained effort. The ACOT study suggested that at least two to three years are required for any shifts in deep practice to occur—an estimate consistent with the findings of the Morsink et al. study.

The second finding of the ACOT study was that successful technology integration entails making changes to the traditional classroom environment. With regard to student learning, it appeared that success depended on transitioning to a more constructivist

environment in which students were actively engaged and empowered in their own learning. Students thrived when they were able to make flexible and adaptive use of new technologies. Morsink and his colleagues found that the same is true for teachers. Progress in the TPACK framework required teachers to be actively and adaptively engaged, considering possible changes to pedagogy and curriculum from multiple perspectives, and balancing competing priorities. Implementing off-the-shelf, one-size-fits-all approaches to technology integration was not an option. Given that change appears to require this kind of constructivist learning, it is perhaps not surprising that teachers in this study travelled such a wide variety of “trajectories,” moving at different speeds, and experiencing different kinds of triumphs and setbacks.

The shift away from more traditional “delivery” or “transmission” models of education is long overdue. Interactive approaches to learning should take the place of lecturing and other forms of passive instruction that assume that students’ minds are *tabula rasa*. The global nature of the world, the influence of media and technologies, the ability to acquire content knowledge using the Internet, the increasing importance of developing 21st-century skills of collaboration, creativity, and critical thinking among others, require a constructivist learning environment. That the authors of this study chose TPACK as a model for helping teachers to acquire and integrate technological, pedagogical, and content knowledge is an acknowledgment of the need to use 21st-century resources and practices to involve both teachers and students in their own learning. (For a review of the ACOT study see <http://fno.org/jun02/teachingreview.html>.)

The second project was the work of ISTE, an independent, non-profit organization of teacher educators and researchers who are dedicated to supporting the integration of technology and improving teacher education across the globe. ISTE has developed National Educational Technology Standards (NETS) for teachers, students, and administrators and identified 14 Essential Conditions that are critical for any type of integration of technology in a school or any other learning environment. All of these conditions are important and necessary for technology to truly have any impact. (For a list of the conditions see <http://www.iste.org/standards/nets-for-students/nets-for-students-essential-conditions.aspx>.)

The findings of the ACOT study and the ISTE project can inform future researchers and practitioners as they seek to understand and apply shifts in pedagogy and develop learning environments that are required for successful technology integration. In particular, the ISTE list of favorable conditions might guide the readers of

Morsink et al. as they apply the findings of this work to their practice. Finally, both ACOT and ISTE place the work of Morsink et al. within the larger context of research on educational technology.

In their conclusion, Paul Morsink and his colleagues point to the need for more longitudinal research on teachers' learning progressions for technology integration expertise, in particular "investigations of how the kinds of learning trajectories described in this study may, over time, fit within overarching, career-spanning learning progressions" (p. 15). In the evolving body of research on technology integration, their recommendation is a promising direction for future exploration.

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Websites

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