Teacher Paradigm Shifts for 21st Practice Skills: The Role of Scaffolded Reflection Within A Peer Community

Cheryl Ann Madeira, James D. Slotta
Ontario Institute for Studies in Education, University of Toronto
cheryl.madeira@utoronto.ca, jslotta@gmail.com

Abstract: This paper presents a longitudinal study of teacher professional development that supports teachers through two interventions, namely scaffolded reflection and peer-exchange, and enables teachers to strengthen their learning of complex Web 2.0 practices within a community of learners. Teachers develop such knowledge only through authentic classroom practices. Nine secondary science teachers (N=9) designed, enacted and revised a technology-enhanced inquiry-based lesson. Teachers’ ideas, lesson plans and reflections were recorded, and their classroom enactments were captured on video in order to connect to their shifts in practice.

Introduction
In science education, a broad community of scholars have focused on the need for “21st century knowledge skills” including inquiry, collaboration, data-sharing, and critical thinking, as well as a wide spectrum of ‘digital literacies’ (Slotta & Linn, 2009; Songer, 2006; Scardamalia, & Bereiter, 2006). These researchers are developing powerful new forms of inquiry that leverage Web 2.0 technologies, engage students in evidence-based reflection and critique, and promote an understanding of contemporary science. As academic research progresses toward new standards and expectations for K-12 science (e.g., AAAS project 2061; NRC, 2011; Partnership for 21st Century Skills, 2009) – schools and teachers must find a way to transform their own conceptualizations and treatments of science. However, science teachers often hold traditional views about the nature of and learning of science, and they lack effective models of professional development that will enable them integrate new inquiry and technology practices (Fishman et al., 2003). Thus, if teachers are to re-conceptualize their approaches to teaching science, they must be supported in their efforts to design and enact curricula that will engage students in authentic forms of 21st century science practices. In order to support such a shift in science education, teachers require in-service professional development that will direct them to learn about, apply, and reflect on the success of new pedagogical applications of inquiry and technology. This paper presents a longitudinal study of teacher professional development that supports teachers through two interventions, namely scaffolded reflection and peer-exchange, and enables teachers to strengthen their learning of complex Web 2.0 practices within a community of learners.

This design-based research examines two important mechanisms for teacher knowledge development: reflection and peer exchange. Nine science teachers participated in online and face-to-face scaffolded reflections and exchanges that were designed to connect directly to their relevant professional practices (i.e., lesson planning and lesson enactment) and to promote collaboration. The impact of these scaffolded reflections was examined during three stages: (1) teacher lesson planning, (2) enactment, and (3) revision of lesson. A coding schema was designed specifically for lesson planning and enactment utilizing a particular formalism of Activity Theory, drawn from Cultural Historical Activity Theory (Engöstrom, 1987). This paper provides a rich description of how individual teachers developed understandings within the context of lesson planning and contributes to our understanding not only of situated collaborative learning, but also offers insight to models of teacher professional development. This paper will argue that teachers developed knowledge as direct result of these experiences.

Theoretical Considerations
There is a substantial body of literature on teacher knowledge (De Jong, 2003; Gess-Newsome, 1999) and teaching professional development (Gerrard et al., 2011; Lawless and Pellegrino, 2007). Scholars have begun to clarify different kinds of knowledge held by teachers, including an understanding of Content Knowledge (CK), general instructional strategies (Pedagogical Knowledge, PK), specific student misconceptions and student learning difficulties (Gess-Newsome, 1999; De Jong, 2003), and Technology Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2005). The difficulty in understanding about teacher knowledge is its implicit nature especially as it relates to their instructional practice. Special artifacts such as wiki lesson plans, and teacher wiki scaffolded reflections can help capture the tacit nature of teacher knowledge development and suggests the possibility of a shared knowledge among teachers.

Reflection is a cognitive process that helps learners to construct their own coherent understandings (Slotta & Linn, 2009). Journaling can deepen teachers’ understanding of their learning, the quality of their learning, and strengthen their understanding of the experience (Moon, 1999). However, while most teachers would acknowledge that reflection is an important professional practice, they don’t make an effort to incorporate explicit reflective activities in their own learning processes (Hargreaves, 1992).

In addition, peer exchange of ideas and experiences about student learning and enactments of lessons, assists teachers in gaining insights they may not otherwise have recognized (Davis, Smithey, & Petish, 2004). The notion of collaborative learning implies a relationship between individual and group, and reflects the position that social interaction provides not only background but also the context for the learning itself (Dillenbourg, 1999). Hoadley and Kilner (2005) reported that many teachers value collaborative practices and ultimately seek to initiate a community of practice that can provide opportunities for learning, peer exchange, and sharing of ideas. Such community-based exchanges can help individuals to better understand their own practice and can facilitate the construction of new knowledge (Scardamalia & Bereiter, 2003). Hoadley and Kilner argued that knowledge artefacts that are constructed, shared, and reconstructed by individuals within the community benefit all community members through shared context and reflection.

Teachers utilize prior knowledge in their teaching practice, but with respect to technology and 21st Century skills, they lack in personal, pre-service and professional development experiences (Davis, 2003). This study investigates how scaffolded wiki reflections provide contextually relevant opportunities for teachers to build understandings that connect directly to their instructional practices, patterns of interaction, and achievement within their classroom. It builds on the aspects of collaborative learning of technology-enhanced inquiry-based lessons. This study reasons that through the mechanisms of reflection and peer-exchange mediated by Web 2.0 tools, teachers can incorporate similar mechanisms within their inquiry-based lessons, and develop "adaptive expertise" (Schwartz et al., 2005) about 21st Century science practices within their classes.

**Methodology**

This iterative, design-based study examined science teachers as they co-designed, enacted, and revised a technology-enhanced, inquiry-based lesson. After an initial interview about their existing ideas concerning project-based learning and technology, teachers were shown a generic set of characteristics for Project-Based Learning (Laffey et al., 1998; Blumenfeld et al., 1991) and reminded of various technologies including productivity software (e.g., Microsoft Office), visualization tools (e.g., Inspiration) social technologies (e.g., wikis or blogs) and interactive learning environments (e.g., WISE: The Web-based Inquiry Science Environment). Next, they worked closely with a mentor to design a project-based lesson, and integrated technology in a meaningful way. Reflections were collected at the time of lesson design, during classroom enactment, during assessment activities, and as the lesson was being redesigned. The teachers met at various at several points during the iterations to discuss and share their experiences with technology and inquiry-based implementation.

**Participants**

There were nine science teachers (N=9) who volunteered to participate in this study, with a range of experience and disciplinary expertise (i.e., physics, biology, chemistry, or general science). The teachers were from 5 different schools located in a large urban city in North America and had a wide variety of technology supports provided by their school base. They were randomly selected because of their interest in technology and initial understanding about project-based lessons. For confidentiality, all participants were given pseudonyms (see Table 1, p 4). All lessons were co-designed by the teacher working closely with the mentor, a doctoral student with 17 years of teaching experience.

**Figure 1.** Teacher Participants Technology-Enhanced Co-Design Meeting
Materials and Data Sources

**Pre-survey and Interview:** In order to establish a measure of teachers’ background and pedagogical content knowledge, a pre-survey was administered to all teachers, followed by an interview for purposes of clarification and to orient the teacher to the study. The following questions were among those given to teachers before starting the research project: (1) What are some of your best learning experiences and why do you think they were important?; (2) What are some of your visions within your science classroom?; (3) What are some of your previous project-based lessons that you have conducted?

**Lesson Plan Template:** A wiki site was designed with specific scaffolding categories for the teacher to design their new technology-enhanced project-based lesson. Some sample categories were (1) “Determining Topic”, (2) “Challenges for students in science topic?”, and (3) “How can technology help?”.

**Teacher Lesson Designs:** Teachers co-designed a technology-enhanced project-based lesson using the scaffolded wiki-template with the research-mentor and their peers in the community. These lessons targeted a project-based learning pedagogy and included a variety of technology tools and materials. The lessons themselves were a focus for analysis. The table below provides an overview of the basic science topics and technology-enhanced project-based lesson themes selected by each teacher.

---

**Table 1. Technology-Enhanced Project-Based Lessons**

<table>
<thead>
<tr>
<th>Teacher Participant</th>
<th>Grade Level</th>
<th>Science Concept</th>
<th>Technology-enhanced PB Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bill</td>
<td>10</td>
<td>Chemistry Indicators</td>
<td>Photo Journal/Wiki/Poster of Experiment</td>
</tr>
<tr>
<td>Merle</td>
<td>12</td>
<td>Physics – interdisciplinary; several concepts</td>
<td>Wiki/Podcast Walking Tour of Science Exhibits</td>
</tr>
<tr>
<td>Charlie</td>
<td>11</td>
<td>Physics – Sound, Electromagnetism,</td>
<td>Wiki/Video/Experiment Segment of</td>
</tr>
</tbody>
</table>
The online community supported peer exchanges, reviewed lesson plans and fostered discussions about the enactments. Upon completing the lesson plan an update of the ‘lessons learned’ and the ‘things I hope to add to the lesson next time’ was added to the wiki lesson page. Teachers in a community were asked to connect to their peers by asking questions and commenting to this additional wiki page. The wiki site for lesson design and reflection played a significant role in supporting socially constructed knowledge. It enabled teachers and the mentor to make their knowledge visible for themselves and all members of the community. These on-line artefacts became an asset for reference by all members of the community. Figure 4 and 5 displays the Website interface of the on-line community (left) and the face-to-face teacher community environment (right).

**Procedure**

This paper reports on nine science teachers’ development of PCK and their experiences during 3 design phases of curriculum design and enactment. There were three main teacher activities that occurred within each iteration: (1) Lesson design, (2) Classroom enactment, and (3) Revision of lesson design. Data sources include teacher surveys, interview questions, wiki lesson plans, scaffolded reflections (captured in a wiki), videotaped classroom enactments, field notes, student artifacts and wiki responses, teacher peer-exchanges (on a wiki and in group meetings).

The first design phase of the study included four teachers \( (n=4) \) who worked individually with the researcher-mentor to co-design, enact and reflect on a science lesson. The second design phase added five more science teachers \( (n=5) \), increasing the community to a total of nine teachers and one researcher. Consistent with the design-based research paradigm, improvements were made on the reflective prompts (i.e., connecting reflection prompts to lesson planning and enactment) and community elements (face-to-face and online), which marked the beginning of the second design phase. The third phase of the design study continued to refine the scaffolded reflection and community exchange connecting teacher activities of lesson planning and enactment deeply with student prior knowledge, project-based learning and technology implementation.

**Analysis and Findings**

**Analysis**
The data collected were grouped into elements drawn from Grossman’s (1990) taxonomy: pedagogical content knowledge (PCK), content knowledge (CK), pedagogical knowledge (PK), technology pedagogical content knowledge (TPCK), contextual knowledge (CKX). The coded elements became an empirical source to address an Activity Theory (AT) based coding of two activity systems: (1) lesson planning and (2) lesson enactment (adapted from Mzanwa, 2002). For each node of the two respective AT, a qualitative score of 1-3 was assigned and related to identifying elements (e.g., PCK, or Project-Based Learning). For example, the Subject node of each triangle was taken to represent a teacher’s PCK.

**Teacher Knowledge Improvement**

The first three elements of the coding scheme for the lesson planning comprised of a category named “Subject” – and together the score reflected the teacher and their lesson planning knowledge. These three elements are as follows: (a) rationale for content choice, (b) connecting strategy to the subject-domain concept, and (c) understanding of technology and use of it to improve project design. Taken together, these three subject codes provide a measure of pedagogical content knowledge (PCK), including the subconstruct of technology pedagogical knowledge (TPCK). Although PCK and TPCK are seen as abstract terms in the literature, they are valid forms of teacher knowledge and can be measured within the context of authentic teaching practices.

From the analysis, the “Subject” score reflecting some measure of PCK improved from Iteration 1 to Iteration 2 for the participants of this study. Thus, teachers demonstrated improved pedagogical content knowledge in their second planning cycle, as measured by the average score of the three elements. Figure 6, recognizes that at the end of the second design cycle not all the teachers completed two iterations. Three teachers—Merle, Olga, and Maddie—began their first iteration with a community meeting (i.e., they joined the study in Design Phase II), and it is evident from their design and reflections that the peer exchange had a strong influence on their lesson planning. It is suspected these teachers gained some pedagogical knowledge related to project-based technology-enhanced lessons from their initial participation in the peer community.

Isolating the element of technology pedagogical content knowledge (TPCK) from the other elements in the coding schema (i.e., restricting the analysis to the third element only) indicates a similar increase in score from Iteration 1 to Iteration 2 (see Figure 7). These patterns identify the changes in teacher-participants’ understanding about the way in which technology can enhance their lesson. Critical to their growth was reflection about their lesson planning activity, and, indeed, the reflection note they completed during planning was the primary source of coding for this element.

Participants started off at varying levels of understanding about how technology could be embedded within the lesson activity. Technology was an important feature in the design of the project lesson, and as teachers became more aware of its potential, they began to independently incorporate technology as a way for students to share ideas and to scaffold student collaboration. For example, Merle started to realize the student-peers were a valuable resource for each other. As students critiqued ideas of their peers during Merle’s project activity, they began to see that their voice was important, and because of this, Merle began to use technology-based student collaborations in other classroom activities such as note-taking. Bill decreased in teacher knowledge score and had no change in his TPCK score within the lesson design coding schema. Again, this could be linked to his poor wiki reflections (in written form) concerning his lesson design and the student learning processes that he hoped to target with technology.

![Figure 6. Measure of PCK-TPCK Iteration 1 – Iteration 2](image)

© ISLS
Teachers who learned also adopted technology-enhanced project-based practices more effectively. As they participated in the community activities that included wiki reflections and on-line technology sharing, the teachers began to use the techniques of scaffolded peer-feedback on their on class wiki site. The adoption of these ideas offers a plan for teacher learning that includes the use of inquiry mediated by technology.

Table 2 (below) summarizes the teacher-participants in this study with respect to project-based teaching and technology experience, with teachers’ scores based on the lesson planning and enactment schemas. The range of values from -3 to +3 allow teachers to be placed within a two dimensional matrix, which offers some measure of their baseline experience and understanding of project-based learning and technology, respectively.

Table 2. Summary Initial Teacher Understandings of Project-Based and Technology-Enhanced Lessons

<table>
<thead>
<tr>
<th>Teacher-Participant</th>
<th>Project-based Learning</th>
<th>Technology-Enhanced Lesson</th>
<th>Comments on Participant Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charlie</td>
<td>-1</td>
<td>-1</td>
<td>Some understanding of technology but design of project-based lesson—didn’t use affordances at start (limited community but grew)</td>
</tr>
<tr>
<td>Daryl</td>
<td>-3</td>
<td>-3</td>
<td>Only used PowerPoint—not effective understanding of wiki (limited community)</td>
</tr>
<tr>
<td>Frank</td>
<td>-1</td>
<td>1</td>
<td>Used WISE and customized it (limited community)</td>
</tr>
<tr>
<td>Bill</td>
<td>-2</td>
<td>-3</td>
<td>Limited use of technology, some understanding of project-based learning (limited community)</td>
</tr>
<tr>
<td>Merle</td>
<td>2</td>
<td>-2</td>
<td>Great project-based—but nervous at beginning about technology (was beneficial and benefited from community)</td>
</tr>
<tr>
<td>Maddie</td>
<td>-1</td>
<td>-2</td>
<td>Weak in both areas (although was able to benefit from the study’s community)</td>
</tr>
<tr>
<td>Olga</td>
<td>-2</td>
<td>-2</td>
<td>Had some understanding in both areas (although was really able to benefit from the study’s community)</td>
</tr>
<tr>
<td>Alex</td>
<td>-2</td>
<td>-2</td>
<td>Enthusiastic, but limited use of technology (benefited from community)</td>
</tr>
<tr>
<td>Placido</td>
<td>-3</td>
<td>-3</td>
<td>Really used the same form of project as Alex—he had limited use for project-based learning (resistant to change) (benefited from community)</td>
</tr>
</tbody>
</table>
Figure 8 provides an overall sense of teachers’ initial experiences at the outset of their participation within the study. When the scores from Table 2 are plotted on a two-dimensional grid, only one teacher (Merle) was experienced with project-based instruction, and only one (Frank) had a high level of technology experience. Clearly, all teachers in the study stood to gain from their participation in a reflective process of lesson planning and enactment.

The coding schemes allowed a mapping of several distinct kinds of data, resulting in scores or weights for the various nodes of the activity triangle. While such applications of the activity triangle are not generally favoured by activity theorists, this approach does serve to capture the complex temporal and cultural aspects of an activity like lesson planning (i.e., as opposed to, say, just scoring the teachers’ lesson plans). This coding schema made variables consistent (with common vocabulary) across iterations and across participants. Examining the various activity system nodes allowed an examination and discussion of the individual changes or shifts in practice, as influenced by the teacher reflection.

One way to interpret knowledge development is by examining the teacher knowledge quadrants. While teachers were placed in their initial quadrants via a separate coding rubric (technology and project-based learning), it is possible to examine their movement within the quadrants by utilizing their “Subject” scores, which correspond to PCK and TPCK. The initial quadrants positioned teachers on their understanding of project-based learning and technology. PCK is knowledge that encompasses understanding of how to implement pedagogy (e.g., project-based learning) and TPCK is knowledge that specifically addresses technology enhancements to the pedagogy. Both PCK and TPCK are seen to be similar to the initial measures of project-based learning and technology. Figures 9 and 10 (below) illustrate teachers in the knowledge quadrant diagram after each iteration of planning and enactment.

The initial teacher knowledge grid scoring assesses project-based and technology understanding. This original grid is more representative of teachers’ prior thoughts seen as a more generic or static view of their understanding of project-based learning and technology implementation. However, as the teacher participated in the lesson planning and enactment activity, their understandings were identified more specifically through the rubric scoring as PCK and TPCK. The scores for the project-based dimension were obtained by combining the “Subject” scores (i.e., PCK) for planning and enactment, resulting in a single measure (displayed on the figure), which was then scaled to fit onto the quadrant scale of 1 (weak knowledge) to 6 (strong knowledge). The score for the technology dimension was obtained in a similar way, using only the technology element from the “Subject” nodes.

**Conclusion**

While it is important to realize that teacher reflection and peer-exchange doesn’t require Web 2.0 knowledge, the teachers in this study demonstrated adaptive effective instructional patterns when incorporating technology-enhanced science activities in their class. Teachers did not have a strong technology background but as the research progressed teachers had a paradigm shift about the uses of Web 2.0 and how it would enhance student learning.
The three teacher knowledge quadrants offer a visual representation of the growth in teacher knowledge over the course of this project. They do not say anything about the teachers’ overall level of knowledge. But they can make a specific qualitative claims, that planning, enacting, and then revising an inquiry-based science lesson while reflecting in peer-community can help teachers learn. It also suggests that interventions that model techniques and skills (such as 21st Century practice skills) can help teachers shift in their approaches and develop pedagogy appropriate to teaching 21st Century science.

**References**


