Technology-mediated Reflection and Peer-exchange: Supports for Teacher Professional Development Communities

Cheryl Ann Madeira, James D. Slotta, University of Toronto, 252 Bloor Street West, Toronto, ON, Canada
Email: cheryl.madeira@utoronto.ca, jslotta@oise.utoronto.ca

Abstract: This design-based research study investigates the development of pedagogical content knowledge (PCK) among nine teacher-participants in three design phases. PCK is a particular type of teacher knowledge that addresses not only the teacher's understanding of the content to be instructed, but also ways of how to teach that content effectively. This paper offers a detailed perspective on how teachers developed PCK with their engagement in lesson planning and enactment of a project-based technology-enhanced lesson in relationship to their actions in the class. The study includes two specific interventions designed to enhance teachers' development of PCK: (1) scaffolded reflection, and (2) peer-exchange. The findings presented in this paper focus on the impact of the peer exchange intervention, which was achieved through an online community, combined with face-to-face meetings. Results demonstrate a positive impact of such exchanges on the quality of teachers' lesson designs and enactments.

Introduction and Objectives

How can teachers be supported as they develop their expertise and craft knowledge? Judith Warren Little (2002, p 2) comments, "Long-term observers of educational innovation and school reform have argued that reform might more productively be seen as a problem of learning than as a problem of implementation. That is, the progress of reform appears to reset in crucial ways on the capacity of teachers, both individually and collectively." Often, teacher learning happens in workshops where the topics are selected in a top-down fashion by school boards and ministries of education and lack any explicit connections to what teachers may already know, or any clear approach to engaging them in learning about their practice. In recent years, many educational and cognitive researchers have identified the pivotal role that teacher knowledge and expertise plays in student learning within an inquiry-based environment (Davis & Krajcik, 2005; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Fishman, Marx, Best, & Tal, 2003). How can CSCL technologies and methods support their exchange of ideas, strategies and artifacts about their practice? This paper presents a longitudinal study of a technology-enhanced environment that supported teachers in the online exchange of their ideas and experiences, strengthening their learning of complex practices and their development of community. This design-based study investigated a teacher professional development community and the role that scaffolded reflections and peer-exchange has in teachers' growth of professional knowledge and practices.

Traditionally, teachers have tended to learn through isolated and informal circumstances, disconnected from dialogue or discussion with peers. However, in the Web 2.0 era, social exchanges play a more central role in learning, and technology has changed the ways in which learners make sense of the world (Collins & Halverson, 2010). The research literature identifies two important mechanisms for teacher knowledge development – namely reflection and peer exchange. Reflection is a cognitive process that helps learners to construct their own coherent understandings (Davis, 2006; Linn & Slotta, 2006). Through peer exchange, teachers can share ideas and experiences that lead to insights they may not otherwise have recognized (Davis, Smithey, & Petish, 2004). Technology can offer new ways for teachers to reflect on their practices as they engage in complex activities (Collins & Halverson, 2010) and new ways to interact within a community of peers (Slotta & Linn, 2009) as it provides a temporal space for the exchange of lesson plans, enactment strategies and epistemological understandings about student knowledge and learning.

This research examines a computer-supported teacher community where members co-designed, enacted, and revised project-based, technology-enhanced science lessons. The teachers were scaffolded in online and face-to-face reflections and exchanges that were designed to connect directly to their relevant professional practices (i.e., lesson planning and lesson enactment). The impact of scaffolded reflections was examined during three stages: (1) teacher lesson planning, (2) enactment, and (3) revision of lesson. The impact of peer exchange was investigated by establishing a co-design and discussion process for lesson planning, enactment and revision. Using a wiki layer and accompanying Web site, these two interventions (reflection and peer exchange) were studied through multiple design iterations. This paper provides a rich description of how individual teachers developed understandings within this context, contributing to our understanding of situated collaborative learning, and offering insight to models of teacher professional development.

Theoretical Foundations

Teacher Knowledge and Professional Development

Teachers' Pedagogical Content Knowledge (PCK), critical to the successful adoption of any innovative methods or materials, is defined as the blend of the their understanding of content within subject domain, the epistemological characteristics of learning within their subject domain, and the specific pedagogical practices and characteristics of their subject domain (Shulman, 1986, 1987; Borko & Putnam, 2002; Gess-Newsome, 1999; Loughran, Berry, & Mulhall, 2006). While the tacit nature of PCK, as connected to complex teacher actions within the classroom, hinders efforts to assess or evaluate it, there are several factors that are thought to influence its development, including teacher lesson planning (Magnusson et al., 1999), and teacher reflection (Park & Oliver, 2008). Recently, another form of teacher knowledge, namely technology pedagogical content knowledge (TPCK), has been advanced to describe knowledge that enables the navigation through the complex relationships of content, pedagogical and technology knowledge (Koehler, Mishra & Yahya, 2007). Teacher knowledge can be difficult to measure in the course of any study of classroom practice or professional development. There are some metrics that have been used to document teacher perceptions and beliefs about their own teaching and instructional practice (Loucks-Horsley & Matsumoto, 1999; Stuessy & Metty, 2007). Across a wide spectrum of research on teaching practices, two kinds of interventions have been seen are seen as effective in both monitoring and influencing teacher learning: reflection and peer-exchange (Slota & Linn, 2009). The next two sections of the paper provide a brief review of such research, which sets the context for our own study of these two important interventions.

Scaffolded Reflection

A substantial body of professional development literature has focused on reflective practice as a means of enabling the growth or development of teacher knowledge (Barnett & Coate, 2005). Schön (1983, 1987) offered a theoretical perspective about the growth of teacher knowledge during the course of professional practices, where the silent reflections occurring within the context of classroom activities make knowledge construction tacit. For example, if something catches a teacher's attention during class (e.g., a student misinterpretation of a concept), the teacher may recognize that moment as being significant and ponder on possible changes for the next class or the next iteration of the lesson. While such tacit reflections are likely an integral part of many teachers' practice (McNamara, 1990), limited time is provided for teachers to engage in deliberate reflections that are explicitly linked to classroom events, such as in reflecting about why some lessons are successful and why some are not (Raines & Shadow, 1995). This study recognizes the limitations in reflective practice and uses technology to scaffold and structure reflections that target various teaching practices of planning, enactment and revising of lessons. This type of reflective practice draws on an understanding of scaffolding for reflection, a general process where learners are supported with technology-based prompts or tools that enable them to achieve knowledge that might otherwise be ignored (Slotta & Linn, 2009; Fishman et al., 2003).

Teacher Communities and Peer-Exchange

The notion of a peer community suggests opportunities for social interaction, mutual dependence, and group identification, with (in the case of teachers) possible connections to classroom events (Westheimer & Kahne, 1993). Such a structure, should it ever be achieved, could be seen as reflecting Lave and Wenger's (1991) notion of a Community of Practice, in which participants' knowledge of practice is rehearsed both explicitly and implicitly. Palinscar et al. (1998) have suggested that if learning, thinking, and knowledge construction are inextricably connected to social contexts, then providing opportunities for teachers to engage in meaningful deliberation, interaction, and reflection within a community of peers would help to nurture their practice and professional development.

Following other approaches to establishing online communities, such as MERLOT (McMartin, 1997), Tapped In (Schlager et al., 2004) and MSPnet Hub (Falk & Drayton, 2004), this study defined online community as a persistent space for teachers to share approaches and interact with peers, serving not only as a digital resource, but a virtual space for collaborations (i.e., in lesson planning) and reflection (i.e., regarding lesson enactment). Participation or engagement within such a community can be measured in terms of contributions of materials (e.g., lesson plans, reflections or comments) and engagement in peer exchange (e.g., adding comments to one another's postings). Such online resources can help teachers to connect with peers across physical distances and asynchronously, allowing access for a wide range of participants. In the present study, the community consisted of a wiki, with an accompanying website, providing a space for persistent and continuous knowledge for the teachers to draw upon.

Methodology

This three-year, iterative, design-based study investigated teacher professional development as it occurs in the rich context of a curriculum-design community, where nine science teachers (N=9) each designed, enacted, and

revised a technology-enhanced project-based lesson. The lessons were designed according to a generic set of characteristics for Project-Based Learning (Laffey et al., 1998; Blumenfeld et al., 1991) and used 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). This study focused on the role of two primary forms of intervention in teacher's development of PCK: reflections and peer-exchange within a community. Iteration 1 included scaffolded reflection and limited community. In Iteration 2, design improvements included improved scaffolded reflection (more deliberate to project-based learning and content), and introduced peer-exchange.

Participants

There were nine science teacher participants (*N*=9) with a range of experience and disciplinary expertise (i.e., physics, biology, chemistry, or general science). Figure 1 illustrates participants' teaching experiences and subject expertise. They were selected based on their expressed interest and content knowledge, and were surveyed about their initial understandings of project-based instruction and technology. Teachers came from 5 different schools located in a large urban city in North America and had access to a fairly wide range of technology supports (i.e., as provided by their schools). The teachers and research-mentor formed a co-design team. The research-mentor was doctoral student who also had 17 years of experience teaching in secondary science classes.

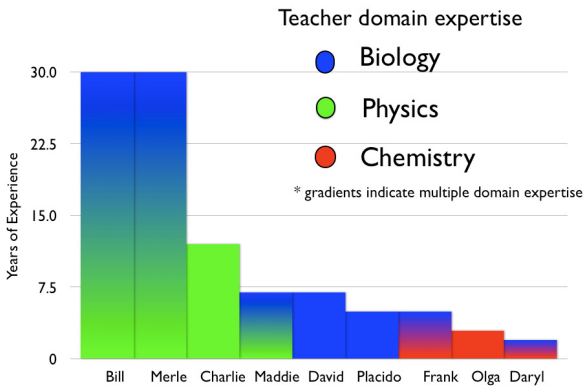


Figure 1. Teacher Participants - Years of Experience and Subject Expertise.

Materials

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 include 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.

Teacher Participant	Grade Level	Science Concept	Technology-enhanced PB Lessons
Bill	10	Chemistry Indicators	Photo Journal/Wiki/Poster of Experiment
Merle	12	Physics – interdisciplinary; several concepts	Wiki/Podcast Walking Tour of Science Exhibits
Charlie	11	Physics – Sound, Electromagnetism, Newton's Laws	Wiki/Video/Experiment Segment of concept
Maddie	11	Physics – Newton's Laws, Renewable Energy	Wiki/Video/Experiment Segment of concept
Frank	7/8	Ecology – Wolves management program	Wiki/WISE/Video Wolves Ecology Commercial
Placido	7/8	Earth and Space – Earth's Crust project	Wiki//Video/Powerpoint Presentation
Alex	7/8	Earth and Space – Earth's Crust project	Wiki//Video/ Powerpoint Presentation
Olga	12	Chemistry – interdisciplinary; several concepts	Wiki/Poster/Debate-Presentations
Daryl	9	Biology – Reproduction; Physics – Reusable Energy	Wiki/ Powerpoint Presentation

Reflection Questions: A wiki site and specific scaffolded reflection prompts were designed to capture teachers' understandings about pedagogical content. Reflection questions were asked at three different points in each teacher's lesson planning and enactment process:

- Prior to the lesson planning: (1) What are the goals of your lesson? (2) What are your thoughts about the student ideas? (3) What are some of the key elements in your project-based design?
- After the lesson planning: (1) Where do you think the students will be challenged? (2) What will you try to do with your time, during the lesson? (3) What are some of the follow up concepts that require set up during lesson?
- After the lesson enactment: (1) Did you find the students had more or less difficulty than you expected? (2) What is one change or addition you would like to put into place for next time? (3) What was one advantage in using the technology within the project-based activity?

Community: The peer community within this project includes both offline and online components. The teachers had periodic community meetings where they exchanged ideas and shared their stories about the project-based enactment, which served to establish a personal relationship between community members. The online component of the teacher community consisted of a website and a wiki site, developed to collect personal statements from teachers about their background and philosophy, as well as to collect details of lesson plans, and all reflections.

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 assets for reference by all members of the community. Figure 2 displays the Website interface of the on-line community (left) which linked to Figure 3, the wiki space (right).

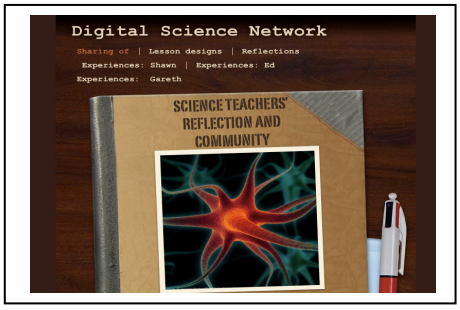


Figure 2. Teacher Web Interface.

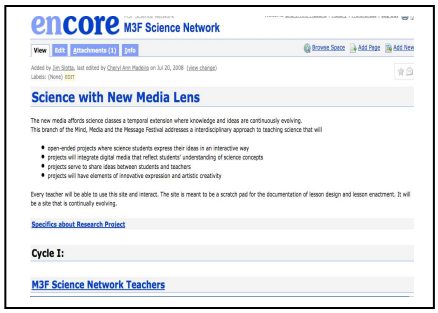


Figure 3. Teacher Wiki-community Site.

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).

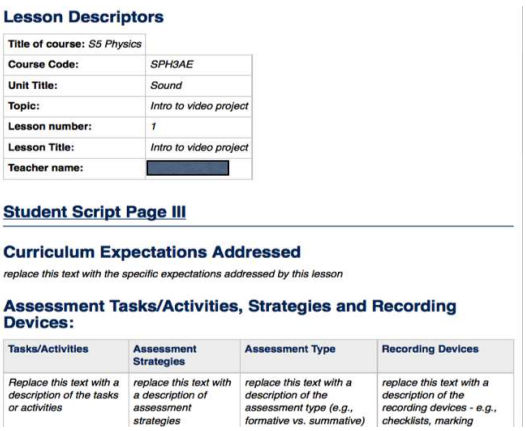
The first design phase of the study included four teachers (n = 4) who worked individually with the researcher-mentor to co-design, enact and reflect on a science lesson. The second design phase added five more science teachers (n=5), increasing the community to a total of nine teachers and one researcher. 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

Community Exchange of Content

The online teacher community helped to make teacher ideas and actions more visible, accessible, and persistent, fostering scaffolded discussions about how to revise lesson plans and helping to focus teachers' thinking on issues of student learning. Figure 5 shows a screen capture of one teacher's (Charlie) lesson plan and Figure 6

shows a sample of a student artifact that he posted for his peers: a digital resource he had created, consisting of a wiki page to support students' planning for a video project. Such sharing allowed other teachers to see how their peer had set up lesson plans and how his lesson had taken form in students' hands. The community was able to read Charlie's lesson plan and his reflections about it, and add their own comments (Figure 7). The teacher-participants could follow the changes that Charlie made to this lesson from Iteration 1 to Iteration 2, as well as his rationale for those changes, and see the resulting impact on student work.



Lesson Descriptors

Title of course: *S5 Physics*	
Course Code:	*SPH3AE*
Unit Title:	*Sound*
Topic:	*Intro to video project*
Lesson number:	*1*
Lesson Title:	*Intro to video project*
Teacher name:	[redacted]

Student Script Page III

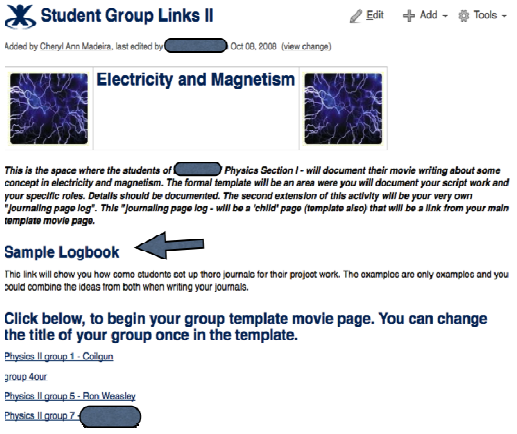
Curriculum Expectations Addressed

replace this text with the specific expectations addressed by this lesson

Assessment Tasks/Activities, Strategies and Recording Devices:

Tasks/Activities	Assessment Strategies	Assessment Type	Recording Devices
Replace this text with a description of the tasks or activities	*replace this text with a description of assessment strategies*	*replace this text with a description of the assessment type (e.g., formative vs. summative)*	*replace this text with a description of the recording devices - e.g., checklists, marking*

Figure 5. Charlie's Lesson Plan—Iteration 1.



Student Group Links II Edit Add Tools

Added by Cheryl Ann Madeira, last edited by [redacted] Oct 08, 2008 (view change)

Electricity and Magnetism

This is the space where the students of [redacted] Physics Section I - will document their movie writing about some concept in electricity and magnetism. The formal template will be an area were you will document your script work and your specific roles. Details should be documented. The second extension of this activity will be your very own "journaling page log". This "journaling page log - will be a 'child' page (template also) that will be a link from your main template movie page.

Sample Logbook

This link will show you how some students set up there journals for their project work. The examples are only examples and you could combine the ideas from both when writing your journals.

Click below, to begin your group template movie page. You can change the title of your group once in the template.

Physics II group 1 - Colligan

group 4our

Physics II group 5 - Ron Weasley

Physics II group 7 [redacted]

Figure 6. Student Wiki-template Iteration 2; with Lesson Design Improvements Including Student Reflection.

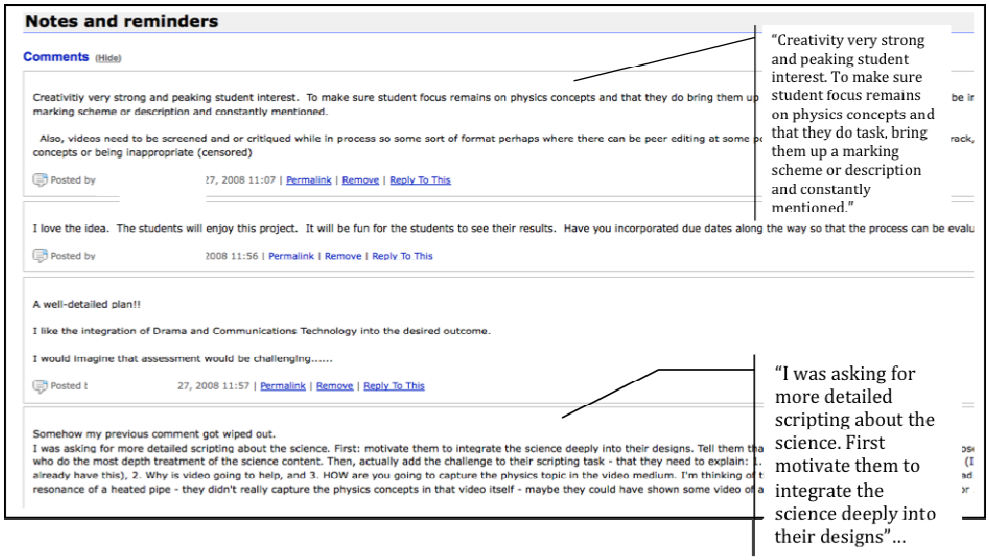


Figure 7. Community Reflections on Lesson Plans (comm27/08/08).

In the community meetings, Charlie described how his video project had allowed students to express their own understanding of physics topics, but also detailed where the lesson design activity had fallen short in engaging them. As he planned his second iteration, he published his improvements to the community Website. He introduced wiki logbooks to help students make sure that they documented what they were doing throughout the process. After enacting this version twice, Charlie made substantive revisions in Iteration 3, introducing improvements to his wiki support materials (for students) to help make the lesson design more visible to students as well as to his peers in the community.

Teacher Engagement

Teachers who had entered this project with limited understandings of technology were able to experience, through their own engagement within the online environment, how the use of the various technology tools could have potential benefits within their classrooms. The use of the Website as a portal for the community allowed

teachers to easily follow lesson plans, reflections, and video clips of their peers' enactment. It offered an effective means of organizing teachers' artifacts and reflections and supporting their participation.

Teachers' participation within both the online and face-to-face community elements was coded from 1 (lowest) to 4 (highest) based on a rubric that examined three aspects of community engagement: (1) Did the participants provide or find strategies for project-based learning? (2) Did the participants provide or find effective uses of technology? (3) Did the participants provide or find strategies for promoting student inquiry and learning? Other areas such as content sharing and reflection were seen as implicitly fitting within those three elements. Thus, teachers scored highly on this rubric when they had provided lesson plans and student artifacts, discussed their strengths and limitations with peers, reflected on the challenges and strengths of their enactments, and shared their assessment and lesson revisions. Teachers scored lower when they contributed little to the reflections or comments within the online space or face-to-face meetings. A score of 1 was awarded as the lowest possible measure, acknowledging that all participants did have some level of social engagement - at least with the mentor. The face-to-face community involvement was scored and ranked in a manner similar to the scoring used for online participation, providing a simple qualitative measure of participation in meetings or online tasks. Table 2 provides all scores and gives a brief explanation of the teachers' participation in online and face-to-face activities.

Table 2: Community engagement (averaged time of involvement with the study).

Teacher-Participant	Face-to-face Engagement		Online Engagement		Total Score	Comment about Participant Engagement in Community (evaluated the number of times attending and items contributed in the community)
	High	Low	High	Low		
Charlie	4		4		8	Attended every community meeting, and always participated online; shared artefacts, assessments, and reflections
Merle	4		4		8	Attended every community meeting, and always participated online; shared artefacts, assessments, and reflections
Maddie	4		4		8	Attended every community meeting, and always participated online; shared artefacts, assessments, and reflections
Olga	3		3		6	Attended 3 community meetings, and always participated online; shared artefacts, assessments, and reflections
Alex	3		3		6	Attended 3 community meetings, participated online, shared artefacts and reflections and participation online; shared some assessments
Frank		2		2	4	Attended only 1st community meeting, and limited participation online; shared artefacts, assessments, and reflections (no job next term)
Bill		1		1	2	Attended only 1 community meeting, video taped himself for one community meeting, limited participation online; limited sharing
Placido		1		1	2	Attended only 1 community meeting, very limited participation online; shared artefacts, assessments, and reflections
Daryl		1		1	2	Never attended community meetings, no participation online; shared artefacts, assessments, and reflections (before online community).

Figure 8 positions places teachers along a two-dimensional grid of online and face-to-face participation in the study. Each teacher's position is obtained from Table 2, and represents the level of participation observed in each dimension. Further, an overall engagement score for participation or engagement in community can be obtained by summing the two dimensions. It is interesting to note that those teachers who scored low in one form of community (e.g., online) also scored low on the other (e.g., face-to-face). In other words, teachers either appear in the lower left or the upper right quadrants.

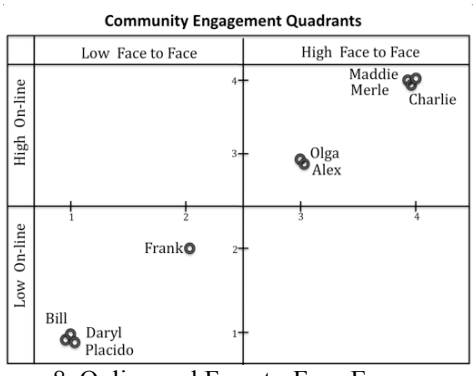


Figure 8. Online and Face-to-Face Engagement.

While the two-dimensional grid may seem arbitrary, it offers a depiction of how well teachers engaged in the community intervention. This measure can also be used to validate the scoring of the Community elements in the next section. The data sources for the Community elements were from scaffolded wiki reflections, interviews, and field notes. These could be viewed as more subjective and had a quality score. The community engagement score was a numerical value of participation. For the purposes of this paper, only Community element with lesson planning will be described.

Community Impact on Lesson Planning

To evaluate the impact of the community intervention, we developed a coding scheme and scoring rubric that captured teachers' participation relative to the available community supports (i.e., in any given design phase of the study). Peer exchange influenced lesson planning, as teachers became aware of other teacher-participants' projects and discussed lesson planning during community meetings. They were able to access lesson plans from the wiki site, observe student artefacts, and read their peers' reflections about enacting the lessons. The Community elements within the Lesson Planning rubric focused on explicit interactions with mentor and peers. Indeed, one element in the rubric was called "Interaction with mentor," and the other was called "Influence of community" (see Figure 9). Each of these elements was scored according to the rubric on a 1 (lowest) to 3 (highest) scale. The following ranked excerpts illustrate the different coding scores for the element "Interaction with mentor."

Rubric: Score of 1. Response indicates limited mentor influences. Answer has limited use of mentor for technology.

Excerpt: *[Participant wrote not applicable] N/A (Daryl 301107)*

Rubric: Score of 2. Response indicates some use of mentor influences. Answer has some use of mentor for technology.

Excerpt: Sharing ideas[with technology], cooperation and working together, team building, working together[with wiki], and trusting that everyone (teachers and mentors) participates and puts an effort. (Frank 280508)

Rubric: Score of 3. Response indicates strong use of mentor influences. Answer has strong use of mentor for technology.

Excerpt: *I would not have been able to consider the changes to the lesson or even trying this video project-based lesson without the community, without you* [researcher-mentor], *so it has changed me and my perspectives giving me things to think about…student-peer exchange and scaffolding their understanding. (Charlie 291008)*

The average Community score was tallied for all teachers across their two iterations. Figures 9 and 10 show that this community score correlates with the lesson planning overall score for Iteration 1 and Iteration 2, respectively. These correlations were both marginally significant, with $F < 0.05$, and $F < 0.07$, respectively. This provides some evidence of a link between teachers' community influence during lesson planning and the quality of their lesson design process. This suggests that teachers can improve in lesson planning by engaging in peer exchange. Given that reflection was also seen to impact on lesson planning, the combined effects of reflection and community should be an even more effective means of professional development.

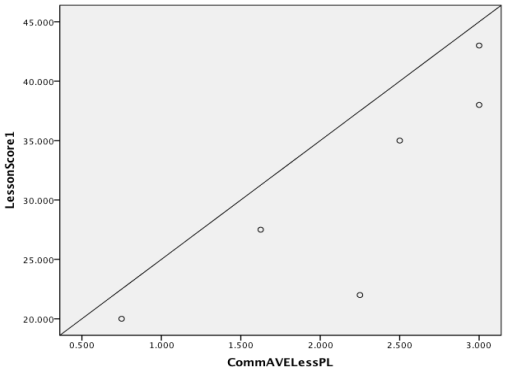


Figure 9. Correlation of Lesson Planning Score and Community Average Score Iteration I.

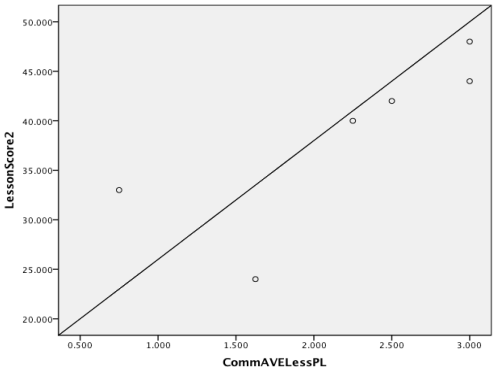


Figure 10. Correlation of Lesson Planning Score and Community Average Score Iteration 2.

Conclusions

Through the use of CSCL tools like scaffolded reflections and peer exchanges, teachers in this study gained a deeper understanding about project-based instruction and translated it into practice within their classrooms. The technologies used within this study offered ways for teachers to exchange their reflections, lesson plans, strategies and student artefacts. The technology also supported the design-based methodology of this study, as

teachers were able to progress between iterations in reference to their wiki-based lesson plans and templates. This allowed for more informed improvements to the lesson plans, and also allowed for the iterative refinement of the scaffolded reflections and peer-exchange prompts and activities. This research provides support for a model for professional development that engages teachers through active reflection and exchange of ideas and experiences with peers, supporting their understanding of new practices and their development of peer communities.

References

Barnett, R., & Coate, K. (2004). *Engaging the curriculum in higher education*. Maidenhead, England: McGraw-Hill/Open University Press.

Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3/4), 369–398.

Borko, H., & Putnam, R. T. (1996). Learning to teach. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 673–708). New York, NY: Macmillan.

Collins, A. & Halverson, R. (2010). *Rethinking Education in the Age of Technology: The Digital Revolution and Schooling in America.* New York: Teacher College Press.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3–14.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5–12.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome & N. G. Lederman (Eds.), *PCK and science education* (pp. 3–17). Dordrecht, the Netherlands: Kluwer Academic.

Falk, J., & Drayton, B. (2004). State testing and inquiry based science: Are they complementary or competing reforms? *Journal of Educational Change, 54*(4), 345–387.

Fishman, B., Marx, R., Best, S., & Tal, R. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*(6), 643–658.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content pedagogy & technology. *Computers & Education, 49,* 740–762.

Laffey, J., Tupper, T., Musser, D., & Wedman, J. (1998). A computer-mediated support system for project-based learning. *Educational Technology Research and Development, 46*(1), 73–86.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York, NY: Cambridge University Press.

Little, J.W. (2002) Locating learning in teachers' professional community: Opening up problems of analysis in records of everyday work. *Teaching and Teacher Education 18* (8), 917-946.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene. *School Science and Mathematics, 99*(5), 258–271.

Loughran, J., Berry, A., & Mulhall, P. (2006). *Understanding and developing science teachers' pedagogical content knowledge*. Rotterdam, Netherlands: Sense.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95–132). Dordrecht, the Netherlands: Kluwer Academic.

McMartin, F. (2008). Open education through open educational resources. In T. Iiyoshi & M. S. V. Kumar (Eds.), *Opening up education: The collective advancement of education through open technology, open content, and open knowledge* (pp. 135–178). Cambridge, MA: MIT Press.

McNamara, D. (1990). Research on teachers' thinking: Its contribution to educating student teachers to think critically. *Journal of Education for Teaching, 16*(2), 147-160.

Palincsar, A. S., Magnusson, S., Marano, N., Ford, D., & Brown, N. (1998). Designing a community of practice: Principles and practices of the GIsML community. *Teaching and Teacher Education, 14*(1), 5–19.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38,* 261–284.

Raines, P., & Shadiow, L. (1995). Reflection and teaching: The challenge of thinking beyond the doing. *The Clearing House, 68*(5), 271–274.

Schlager, M. S., & Fusco, J. (2004). Teacher professional development, technology, and communities of practice: Are we putting the cart before the horse? In S. Barab, R. Kling, & J. Gray (Eds.), *Designing virtual communities in the service of learning* (pp. 120–153). New York, NY: Cambridge University Press.

Schön, D. (1983). *The reflective practitioner*. New York, NY: Basic Books.

Schön, D. (1987). *Educating the reflective practitioner*. San Francisco, CA: Jossey-Bass.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(1), 4–14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57(1), 1–22, 57*(1), 1–22.

Stuessy, C. L., & Metty, J. S. (2007). The learning research cycle: Bridging research and practice. *Journal of Science Teacher Education, 18,* 725–750.

Slotta, J.D. & Linn, M.C. (2009). *WISE science: Web-based inquiry in the classroom*. New York, NY: Teachers College Press.

Westheimer, J., & Kahne, J. (1993). Building school communities: An experience-based model. *Phi Delta Kappan, 75*(4), 324–328.