THE DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE IN SCIENCE TEACHERS: NEW OPPORTUNITIES THROUGH TECHNOLOGY-MEDIATED REFLECTION AND PEER-EXCHANGE

by

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This design-based research study investigates the development of pedagogical content knowledge among nine teacher-participants \((N = 9)\) 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 knowledge has been well documented over several decades, and is seen as central to teacher expertise. However, its actual development has been difficult for researchers to investigate. This study offers a detailed perspective on how teachers developed PCK with their engagement in lesson planning and enactment of a project-based technology-enhanced lesson. The study includes two specific interventions designed to enhance teachers’ development of PCK: (1) scaffolded reflection that occurs throughout the practices; and (2) peer-exchange of lesson plans, enactment ideas, and completed reflections.

The findings demonstrate that teachers improve their planning and enactment of project-based technology-enhanced lessons with scaffolded reflection and peer exchange. Positive correlations were seen between teachers’ engagement in the reflections and the quality of their lesson planning. Teachers who participated more deeply in the scaffolded reflections were able to understand how their lesson plans and enactment patterns fostered student understanding of relevant science concepts. Positive correlations were also seen between community influence and teacher lesson plans and enactment. Additionally, positive correlations were confirmed between teachers’ level of participation in the peer exchange activities and the quality of their lesson
planning and enactments. Teachers who contributed more deeply within the online and face-to-face peer community meetings benefited from the different perspectives of their peers about student learning and the best ways to succeed with project-based instruction.

This study allowed some insight into how PCK develops as a result of teachers’ engagement in the complex set of activities that constitute the practices of lesson planning and enactment. The primary implication of this study is that engaging teachers in scaffolded reflections and peer exchange can be a valuable in-service professional development activity. A methodological strength is derived from an approach to coding teachers’ lesson planning and enactment according to an activity systems perspective, drawing on a spectrum of data sources (e.g., wiki-based reflections, planning artefacts, videotaped classroom enactments). Teacher learning—particularly the development of PCK—is recognized as critical in promoting student understanding of science concepts. This dissertation lays out a possible foundation for professional development models that promote effective teacher learning.
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CHAPTER 1:

INTRODUCTION

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.

—Judith Warren Little, Teachers’ Professional Development in the Context of High School Reform

Many factors influence learning and instruction within science classrooms, including the nature of the conceptual domain (e.g., biology or chemistry), student and teacher prior knowledge, and the pedagogical patterns and social interactions that occur. Educational and cognitive researchers have long recognized the teacher’s vital role in defining and creating a meaningful learning experience for students (Davis & Krajcik, 2005; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Fishman, Marx, Best, & Tal, 2003; Hodson, 1998). Because novice teachers are invariably less adept at orchestrating such experiences, the question arises as to how teachers develop expertise within their profession. Surely a teacher’s knowledge develops in response to the myriad of exchanges and events (including patterns of student learning) that happen in his or her classroom over time. Ideally, this should result in a deeper understanding of how students learn within content domain and an ability to bring this knowledge to bear on instructional design and practice. This present research seeks to contribute to the literature concerning how teachers develop such vital craft knowledge (Bullough, Clark, & Patterson, 2003).

As a consequence of their complex and demanding profession, teachers have limited time for professional development and limited energy for reflection about their curriculum efficacy. Innovative pedagogical strategies, such as the use of new technology tools, are often implemented on the fly, and teachers are on their own to develop appropriate strategies. This sense of forced self-reliance can lead to conservative behaviour with regard to the adoption of
new pedagogical approaches. For instance, many teachers recognize that inquiry or constructivist methods are an effective way to help students learn science, yet they fall back on traditional, didactic methods of lecture. Science teachers, particularly at the secondary level, are under a great deal of pressure to complete curriculum expectations and fulfill school policies and regulations. Furthermore, their engagement in teacher professional development is typically removed from their everyday classroom practices, where they feel that they do not have the time to do anything other than teach. As a result, many teachers do not reflect on their practice regularly, they do not develop a metacognitive awareness that reflection is important to professional growth, and they do not benefit from the wealth of opportunity that awaits them within their everyday classroom context.

This study investigates a professional development approach that involved secondary science teachers engaging in reflection directly connected to the authentic classroom practices of lesson planning, enactment, and evidence-based revision. It aims to explore the relationship between those practices and the development of a kind of knowledge known as pedagogical content knowledge (Shulman, 1986).

1.1 Purpose of the Study

Prior research about teacher learning has suggested that in order for teachers to develop their own understanding of learning within their content domain, they must critically examine and reflect upon their interactions with students (Ball & Cohen, 1999; Putnam & Borko, 1997, 2000). This research has helped educators recognize that while teachers may be able to understand new instructional strategies (e.g., project-based learning or inquiry-oriented learning) it is not a straightforward process for them to implement such innovations within their own instruction (Putnam & Borko, 1997). Because teachers are the “key agents when it comes to changing classroom practice . . . the final policy brokers” (Spillane, 1999, p. 144), it is vital that
we understand how they can come to adopt new understandings and practices within their domain.

Fullan and Hargreaves (1992), who conducted an empirical study on education change in Canada, England and the US, also point to the importance of teacher development. Fullan (1991) suggested that teacher professional development has been ineffective in the past, and that in most teacher professional development, “Nothing has promised so much and has been so frustratingly wasteful as the thousands of workshops and conferences that led to no significant change in practice when teachers returned to their classrooms” (p. 315). Cohen and Ball (1999) observed that historically, teacher professional development has been “disconnected from deep issues of curriculum and learning, fragmented and non-cumulative” (p. 15). Workshop topics for teacher professional development are often selected in a top-down fashion by 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.

While many researchers have investigated teacher knowledge (see, e.g., Ball & McDiarmid, 1990; Brophy, 1988; De Jong, 2003; Gess-Newsome & Lederman, 1999; Grossman, 1990; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Park & Oliver, 2008; Roth, 1995; Shulman, 1986, 1987), there remains a gap in our understanding of how this knowledge develops over the course of a teacher’s career (Mulholland & Wallace, 2005). This study looks at a vital form of teacher knowledge known as pedagogical content knowledge (PCK; Shulman, 1986, 1987). PCK is a body of teaching knowledge involving a transformation of knowledge of subject matter into knowledge of teaching about subject matter. There are many factors that can influence the development of PCK: the teacher’s content knowledge within a subject domain, the students’ prior knowledge, the pedagogical approaches employed, the interactions between students and teacher, and the way the teacher reflects on these experiences before, during, and
after the instruction. The somewhat tacit nature of PCK hinders efforts to assess or evaluate it (Magnusson, Krajcik, & Borko, 1999), as well as any effort to scaffold its development (Park & Oliver, 2008).

Researchers concerned with teacher knowledge development recognize that the knowledge and skills gained within any practice are intimately connected to the physical and social context in which the practice takes place (Little, 1999; Putnam & Borko, 1997, 2000). Thus, teachers can best develop new understandings about learning and instruction in their domain by experimenting within the context of meaningful classroom activities. More than “learning by doing,” this perspective argues that certain kinds of learning can only happen through engagement in richly contextualized activities.

The study will investigate the development of teachers’ PCK in relation to their engagement in relevant, classroom-based activities of designing and enacting an innovative project-based lesson (Krajcik, Blumenfeld, Marx, & Soloway, 1994) that integrates technology into scaffolded student inquiry (Slotta, 2004; Slotta & Linn, 2009). One critical aspect of teacher knowledge development is reflection. Specific strategies that support teacher reflection such as journaling (Connelly & Clandinin, 1990), peer observations (Hammersley-Fletcher & Orsmond, 2005), and engagement within a peer community (Thorpe, 2001) have been seen to influence teacher practice. For instance, journaling can deepen teachers’ understanding of their learning and the quality of that learning, as well as strengthen their understanding of the experience (Moon, 1999). However, while most teachers would acknowledge that reflection is an important professional practice, most teachers do not make an effort to incorporate explicit reflection activities in their own learning processes (Hargreaves, 1992). The reasoning for teachers’ lack of reflection practice could be due to time constraints, the demands of the school schedule, and responsibilities of curriculum development and student assessment. This research engaged
teachers in reflection at every stage of their planning and enactment as a specific intervention, and teachers that participated in this study valued reflection as a vital component to teacher professional development.

In addition, Bell and Gilbert (1996) observed that teachers benefit from the social context of reflective engagement with their colleagues. 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 & Beireter, 2003). Hoadley and Kilner argued that knowledge artefacts that are constructed, shared, and reconstructed by individuals within the community can benefit all community members through shared context and reflection.

1.2 Overview of the Study

This dissertation reports the findings of a 3-year, design-based research study aimed at understanding the development of teacher cognition and meta-cognition. A design-based methodology fostered continuous improvements of the research intervention of reflection and peer exchange. In 2006, Design Phase 1 of this study, four teacher-participants were introduced to the ideas of technology-enhanced project-based lessons. The research connected with the naturalistic settings of the teachers’ classrooms (Brown, 1992). Through design-based approaches of revision and iterations (Barab & Squire, 2004), reflective scaffolds for the participants were improved. In spring 2008, in Design Phase 2 of the study, a new group of teachers was introduced and embarked on explicit community interventions. A final community meeting ended the study in June 2009.

This research examined teachers as they codesigned, enacted, and revised their project-based lesson. The teachers, both as individuals and as members of the community, had online
and face-to-face activities structured into their responsibilities. This work drew on the theoretical perspective of social constructivism, a the predominant guiding framework of education research. The rich descriptions of how individuals develop understandings within the context of interactions were apart to address the research questions of this study ultimately to inform models of professional development.

1.3 Research Goals

The first goal of the study was to describe the specific process of teacher reflection as one of reconciling existing knowledge or creating new knowledge in relation to pedagogical activities. This is an important theoretical objective, as this project hopes to describe how the process of reflection can mediate the development of teacher knowledge. Several researchers have investigated the mechanism of reflection as a distinct cognitive process that helps teachers construct understanding (e.g., Davis, 2006; Linn & Slotta, 2006). In other words, reflection is fundamentally a constructivist process, much the way an explanation can serve to build a new understanding in an individual (Chi & Ohlsson, 2005) and can also serve teachers well as a process for developing coherent understandings. This research investigated the role of scaffolded reflections in providing contextually relevant opportunities for teachers to build understandings that connect directly to their instructional practices, patterns of interaction, and achievement within their classrooms.

The second goal was to develop a framework for describing the activity patterns of teachers in relation to the planning and enactment of their technology-enhanced project-based lessons. This framework supported the analysis of the relationships between teachers’ activity patterns and the development of their pedagogical content knowledge. The framework used a formalism called an Activity System Triangle (AT; Engeström, 1987) to interpret the rich array of goals, scaffolds, and constraints, as well as the temporally distributed nature of activities such
as lesson planning (which seldom happen in just one sitting, or even in isolation of other activities). By adopting a formalism from another theoretical tradition, this research hoped to capture the complex interdependencies of subject, object, external rules, community, and division of labour within contextualized teacher practices.

A third goal of this study was to explore how teacher interactions within a community of peers (e.g., access to peer designs, reflections, and social exchanges) could enable the development of teacher knowledge. Student learning in the classroom is a social activity that is commonly interpreted by researchers through a sociocultural lens. Teacher learning can also be viewed in this way, which leads to the insight that teachers may be more effective in their activities when not isolated from peers and mentors. Indeed, the social context of teaching offers an excellent opportunity for professional development that targets social exchanges among peers and mentors in pedagogically meaningful contexts. This approach has been explored by other researchers using videotaped teaching cases and online collaborative communities (Davis, Smithey & Petish, 2004; Derry, 2007; Derry, Seymour, Steinkuehler, Lee, & Siegel, 2004; MaKinster, Barab, & Keating, 2001; Slotta, 2004). My work built upon this thread in the literature, connecting teachers with peers and mentors in the context of their design and implementation of curriculum, as well as connecting through the sharing of their reflections about those activities.

1.4 Research Questions

This study examined the development of teacher pedagogical content knowledge in relationship to lesson design and enactment under the two conditions of reflection and peer exchange. This design-based study investigated the following research questions:
1. How do the activity patterns associated with lesson planning, lesson enactment, and lesson revision contribute to the development of teachers’ pedagogical content knowledge?

2. How does engagement in scaffolded reflection support the development of teachers’ pedagogical content knowledge?

3. How does participation in a community of peers support the development of teachers’ pedagogical content knowledge?

1.5 Significance of the Study

The significance of this research is twofold. First, it investigated the use of reflective practice as an explicit process or method of teacher professional development. As teachers engaged in scaffolded reflection, it was anticipated that they would also develop a deeper understanding of patterns of student and teacher interactions within their classroom that influenced student learning. Second, this study formalized the description of teacher interactions within a community of peers (e.g., access to peer designs, reflections, and social exchanges) and interpreted those teacher interactions through a sociocultural lens. Previous research has shown that teachers work in relative isolation from their peers (Goldsmith & Schifter, 1997; Schön, 1987). However, if learning is seen as a sociocultural activity (Vygotsky, 1978), then not only do artefacts influence individual learning, but social exchange with peers and mentors in the context of pedagogically meaningful activities should also provide an excellent means of professional development. This research helps in understanding how the promotion of teachers’ development of pedagogical content knowledge can occur through engagement in reflection during authentic practices, as well as through participation in meaningful peer exchanges.
1.6 Background of the Researcher

Having taught secondary science for 17 years, I have my own preconceptions and biases about science education and teacher professional development. My own professional learning was enriched with continuous personal journal writing of classroom events and student learning, in addition to dialogue with my peers. These actions were not seen as the norm for teacher professional development and school culture. Furthermore, the school community that I belonged to encouraged colleagues to discuss curriculum and to make strong connections between teacher instruction and student learning successes within their classroom. The impact of my experiences reinforces my belief that two important factors influence teacher knowledge development, namely reflective practices and community exchange, and this type of development has a direct link to student learning within the classroom.

1.7 Outline of Thesis

Chapter 2 of this document provides a comprehensive review of the research and literature on cognitively informed instructional practices, with several important sections: innovative instructional strategies (i.e., project-based learning and technology-enhanced science education); teacher knowledge development; and professional development. Chapter 3 outlines the methodological principles of design-based research, codesign and participatory methods, and activity oriented design-based methods (AODM). The section provides a rationale for the methods used within this study and details of the materials, procedure, data sources, and analytic overview. The results of this study are presented in two chapters: Chapter 4 examines teacher knowledge development in relation to reflection during cycles of lesson planning and enactment, and Chapter 5 addresses teacher knowledge development in relation to teachers’ engagement within a community of peers. Teacher reflections provide not only a means of professional development but also a source of empirical evidence about the growth of teachers’ knowledge.
The findings in these two chapters are based on analysis of coded reflections and other artefacts, such as lesson plans, field notes, video captures, and comments to peers within the online community. Finally, Chapter 6 offers concluding statements from this study, implications, and recommendations for teacher professional development and future research.
CHAPTER 2:

LITERATURE REVIEW

This chapter synthesizes the cognitive and educational literature that informs teacher knowledge development and examines the relationships between teacher knowledge development and teacher instructional practice (e.g., lesson design, enactment, assessment, and feedback).

The chapter begins with a review of the cognitive and sociocultural foundations of learning and then, discusses how these theories are relevant to teacher knowledge, reflection, and peer exchange. Next, it reviews prior research of professional development models and reviews how science teachers can adopt instructional practices. Finally, it examines the large body of literature concerned with inquiry-based instruction in science, including the use of technology scaffolds, which is the instructional strategy that was adopted by teachers in this study.

2.1 Constructivist Perspectives on Learning and Instruction

Conventional instruction, particularly in science topics, focuses on the simple presentation of new concepts to students as “facts out of context” (Duschl, 1990). Such instruction typically engages students in processes of rote memorization and formulaic problem solving (Linn et al., 1996), depriving science students of opportunities to understand science as a process of building and revising models and theories of the world (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Traditional instruction has often been cited as being at odds with a substantial amount of evidence from educational research on student learning (Krajcik, Slotta, McNeil, & Reiser, 2008; Slotta & Linn, 2009). Constructivism is currently the theory of learning within the education field that provides a viable alternative to traditional instruction.
2.1.1 Social Constructivism

Dewey (1916) suggested that experience is the cornerstone from which new knowledge is created, promoting authentic, meaningful experiences that foster new knowledge growth. This perspective gave rise to a theoretical perspective known as constructivism. Widely accepted within the educational community, constructivism describes learning as a process whereby learners actively construct or build new ideas, concepts, or knowledge objects based upon existing understandings.

Piaget, one of the most influential developmental psychologists of the 20th century, provided firm foundations for constructivism by focusing on a child’s learning progression. Piaget (1972) suggested that instructors should empower the individual student to construct his or her own set of meanings in reference to his or her own existing knowledge. He proposed two fundamental processes: (a) assimilation, whereby new ideas are reshaped and fit into a student’s existing conceptualizations, and (b) accommodation, whereby new ideas force a restructuring or reconceptualization (Piaget, 1926). While Piaget’s ideas provide a foundation for constructivist perspectives, they have been critiqued for their notion of universal developmental stages as well as the pre-eminence of content knowledge and subjugation of the learning context.

An important successor to Piaget was Vygotsky (1962), a cultural psychologist who theorized that language and conceptual development are linked to social phenomena and cultural context (1978). Vygotsky (1978) extended the perspectives of constructivism by theorizing that learning occurs through sociocultural mediation, meaning that individuals construct new knowledge through their active participation within a social context and via interactions with its signs and tools. This new theoretical perspective became known as social constructivism, and it focused on the cognitive processes that occur within the context of shared activities (Palinscar, Magnusson, Marano, Ford, & Brown, 1998). Specifically, Vygotsky assumed that although some
learners may be at a certain developmental stage, scaffolding problem-solving activities prompted better learning for the student at various developmental stages (Palinscar, Magnusson, Marano, Ford, & Brown, 1998). Thus, researchers began to recognize that learning and development occur within a continuously changing social and cultural context with appropriate supports.

A number of researchers have emphasized the social and contextual factors in learning (Brown, Collins & Duguid, 1989; Greeno, 1998; Lave, 1988; Lave & Wenger, 1991; Resnick, 1988; Wenger, 1998). Their studies underscore that learning is always embedded within a social and cultural context, and its situated nature elevates and furthers the knowledge within the learner’s community. Lave (1988) observed that it is through participation in practices that are relevant or defining to the community that individuals learn within that social contexts. The next section will describe some pedagogical models for learning and instruction that have been grounded in a sociocultural or community-based perspective.

2.1.2 Prior Research on Sociocultural Models of Learning

In the *reciprocal teaching* model introduced by Palinscar and Brown (1984), teacher and students take turns playing the role of teacher throughout a reading exercise, helping the students successfully develop skills in constructing good questions and making appropriate summaries. A related strategy is that of peer tutoring, where one student (acting as the tutor) addresses conflicts arising from a peer’s learning process. Peer tutoring increases the learners’ organizational and strategic representation of the subject matter, facilitating both general and content-specific understanding and prompting a more solid knowledge framework (Bargh & Schul, 1980; Greenwood, Delquadri, & Hall, 1989). Such mechanisms underlie recent pedagogical approaches such as problem-based learning, in which small groups of peers engage in reflection concerning rich, real-world problems.
An even more general perspective is that of collaborative learning, which refers to a broad class of instructional strategies involving a joint effort amongst students and teachers to develop mutual understanding, solutions, or designs (Smith & MacGregor, 1992), or—even more simply—to learn something together (Dillenbourg, 1999). Research on collaborative learning has shown that students are more satisfied in their work (Slavin, 1980, 1983; Whitman, 1988), that achievement is sensitive to group composition (Dillenbourg, Baker, Blaye, & O’Malley, 1995; Salomon & Globerson, 1987), that group work is more efficient than individual work (Dillenbourg et al., 1995; Littleton & Häkkinen, 1999), and that behaviours and task roles influence the functioning of the collaborative team (Dillenbourg, 1999). The wide collaborative-learning literature emphasizes a shift away from lecture-style classrooms towards a more student-driven environment, where learning is a negotiated process, meaning is shared, and personally relevant problems form the basis of learning (Dillenbourg, 1999; Roschelle, 1992; Roschelle & Teasley, 1995). These pedagogical models emphasize the importance of learners learning and constructing new meaning from other learners.

2.1.3 Constructivist Learning for Teachers

Teachers are also constructivist learners, in the course of their regular practices. Most professional development researchers rely on some constructivist model of learning for teachers (Fishman, Marx, Best, & Tal, 2003; Slotta, 2004). The social constructivist perspective of learning through peer exchange, and engagement in rich, relevant tasks within a community is at the heart of this thesis about teachers’ knowledge development. Sherin and Han (2004) explained that by engaging teachers in a mentored practice of viewing their own lessons and student work they developed a deeper understanding of the situated learning in which their own students must engage. By connecting teachers within a community of peers, they gain opportunities to develop shared understandings and identity. This underscores the need for any professional development
intervention to connect deeply with teachers’ existing classroom practice, as teachers will construct their own understandings based on their engagement in and reflections about those practices. The next section reviews prior research of teacher knowledge, teacher learning and professional development through reflection and peer community—all of which are central to this dissertation study.

2.2 Teacher Knowledge

An important factor in teachers’ adoption of innovative methods or materials is the teachers’ existing knowledge of pedagogy, student learning, relevant disciplinary content, and the specific nature of the innovations to be adopted. Seminal work from Shulman (1986, 1987) articulated a unique form of teacher knowledge called pedagogical content knowledge (PCK). Many scholars have recognized the importance of PCK and defined it as a blend of the teachers’ understanding of content within their domain, the epistemological characteristics of learning within their domain, and the specific pedagogical practices and characteristics of their domain (Borko & Putnam, 2002; Gess-Newsome, 1999; Grossman, 1990; Hashweh, 2003; Loughran, Berry, & Mulhall, 2006; Magnusson, Krajcik, & Borko, 1999; Shulman, 1986). Thus, PCK represents knowledge of subject discipline content, relevant instructional strategies, specific student misconceptions, and student learning difficulties (De Jong, 2003; Gess-Newsome, 1999).

There are a variety of factors that influence the development of pedagogical content knowledge (PCK): the teacher’s content knowledge (CK) within a subject domain, the students’ prior knowledge, the pedagogical approaches employed, interactions between students and teacher, and the manner in which the teacher reflects on these experiences before, during, and after the instruction. The tacit nature of PCK, as it is connected to complex teacher actions, hinders efforts to assess or evaluate it (Magnusson et al., 1999), as well as any effort to scaffold its development (Park & Oliver, 2008). In general, PCK is seen to be intertwined with the
nuanced, often split-second decisions that teachers make on a regular basis (Baxter & Lederman, 1999; De Jong, 2003).

PCK influences teaching interaction and experiences (De Jong, Van Driel, & Verloop, 2005; Van Driel, 2001) helping teachers develop expertise as described through longitudinal studies (Mulholland & Wallace, 2005). Most importantly, PCK can determine the actual experiences of teaching content and in turn can further develop PCK (Van Driel, De Jong, & Verloop, 2002).

PCK has been described as including both an internal construct (i.e., what a teacher knows) and a behavioural or activity-oriented construct (i.e., what a teacher does) (Baxter & Lederman, 1999). Thus, PCK embodies both teacher understandings and teacher actions. Park and Oliver (2008) try to capture this duality of thought and action explicitly within the following definition:

PCK is teachers’ understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments, while working within the contextual, cultural, and social limitations in the learning environment. (p. 4)

PCK can be seen as a form of knowledge similar to that required for playing a musical instrument, flying an airplane, or playing a sport, which entail performance-oriented aspects that can only be gained through practice. Others have compared it with knowledge in a complex domain knowledge such as that of medical diagnosis (Lesgold, Feltovich, Glaser & Wang, 1981) or chess (Chase & Simon, 1973; Wilkins, 1980). In essence, PCK is a form of knowledge that can only develop through complex actions and repeated practice.

The development of PCK could be seen as the means by which a teacher comes to understand effective instruction within his or her specific domain (Gess-Newsome, 1999). This process has been described as a transformation of knowledge such that other relevant forms of knowledge (e.g., content knowledge, classroom management) are synthesized through the
teacher’s engagement in relevant instructional practices (Gess-Newsome, 1999); this interpretation suggests that PCK is mediated by a teacher’s participation in specific activities and processes, such as choosing effective instructional resources or making instructional decisions. However, such activities would rely upon the teacher’s existing knowledge, which has developed, in turn, from earlier teaching experiences. Thus, teaching experiences reinforce the development of PCK, which in turn guides and influences teaching practices.

Another form of teacher knowledge that has been described in recent research literature is that of technological pedagogical content knowledge (TPCK or TPACK) (Koehler, Mishra, & Yahya, 2007; Mishra & Koehler, 2005b; Niess et al., 2009). Those engaged in this research have recognized that in order for teachers to integrate technology effectively within their instruction, they must navigate the complex relationships of content, pedagogical, and technology knowledge (Mishra & Koehler, 2006, 2003). Thus, TPACK is a situated, complex form of teacher knowledge, capturing the fact that teachers need to know not only about the technology but also about how to use the technology to support student learning (Mishra & Koehler, 2003; Carr, Jonassen, Litzinger, & Marra, 1998).

Table 1 outlines several distinct forms of knowledge identified within the literature on teacher knowledge. This description will inform the analysis within this study, as it helps to define various types of behaviours or comments as being representative of certain forms of knowledge. These knowledge descriptors not only serve to identify the various forms of knowledge, they also inform a kind of ranking of the various types of behaviours or comments. Ranking the comments helped position teachers based on their knowledge of project-based lessons and technology. The descriptors enabled the assignment of a quality value to the teacher action seen in the study.
Table 1
Adapted Knowledge Descriptions

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Pedagogical Content Knowledge (PCK)</td>
<td>PCK (as described by Shulman, 1986) is the knowledge not only about a particular domain, but also about how to teach specific topics within that domain. Gess-Newsome (1999) categorizes PCK as either integrative (an interaction or mixture of all teacher knowledge) or transformative (all teacher knowledges are transformed into one teacher knowledge). Some of the elements central to PCK are knowledge of representations (orientation to teaching) of science matter for teaching; knowledge of relevant instructional strategies and curriculum; knowledge of specific student conceptions and understanding; knowledge of student learning difficulties; and knowledge of assessment of students’ learning of subject matter.</td>
</tr>
<tr>
<td>Content Knowledge (CK)</td>
<td>Content knowledge is defined as knowledge of the subject domain specifically. Science knowledge is knowledge about the facts, concepts, and theories of the phenomena in the world. Science knowledge will also involve science problem solving and understanding of scientific literacy or science processes. This knowledge involves knowledge of both the terminology and application.</td>
</tr>
<tr>
<td>Pedagogical Knowledge (PK)</td>
<td>Pedagogical knowledge is defined as knowledge about the strategies used in the science classroom, the instructional knowledge required to teach, curriculum knowledge, the teaching routines involved in management of a class (e.g., taking attendance, group work/collaboration organization, schedules of school classroom), assessment and evaluation, and education goals/visions.</td>
</tr>
<tr>
<td>Technological Pedagogical Content Knowledge (TPACK)</td>
<td>Technological pedagogical content knowledge is the integration of content knowledge, pedagogical knowledge, and technology knowledge. This integration of knowledge also requires understanding of the relationship between the various forms of knowledges.</td>
</tr>
<tr>
<td>Contextual Knowledge</td>
<td>Since knowledge is socially constructed, it makes sense that teachers require a knowledge of the contextual situations in which the learning is occurring. This contextual knowledge can be implicit and explicit. This knowledge includes knowledge about the nation (political knowledge), community (situational knowledge), knowledge of school and board, knowledge of classroom ecology, and knowledge of student community.</td>
</tr>
</tbody>
</table>

*Note.* Adapted from Grossman, 1990 and Park & Oliver, 2008.

PCK development is at heart of teacher learning. Teachers need to understand the content, be effective with strategy choice, and, most importantly, be able to assess student
learning to better inform their next instructional steps. Teacher learning involves not only learning about theories but also how these theories connect to their practice (Darling-Hammond, 1995). The next sections will outline the literature on teacher learning through scaffolded reflection and peer exchange. Understanding teacher learning leads directly to the development of professional development models that allow for collaboratively constructed personal knowledge about teaching through social interactions, as discussed in Section 2.4.

2.3 Teacher Learning

Teacher knowledge can be very difficult to measure, whether in the course of a professional development program or in a research study. Loucks-Horsley and Matsumoto (1999) studied professional development and devised a variety of metrics from Guskey’s theoretical framework (2000) to measure ongoing professional development. They analyzed initial workshops, participant knowledge, teacher support, participant implementation, and student outcomes. Loucks-Horsley and Matsumoto noticed a connection between teacher perceptions and beliefs about their own teaching and learning, and instructional practice. Stuessy and Metty (2007) employed a contemporary model of professional development (Knight & Boudah, 2003), called Learning Cycles of Research (LCR), to focus on one teacher’s learning as she incorporated more scientific research into her science classroom. Their study also documented teacher and mentor perspectives through reflection and review, to gage what was learned over eight stages within a two year period. Stuessy and Metty (2007) identified the importance of relationships formed through professional development in order to close the gap between research and practice. Wilson and Berne (1999) reviewed professional development literature and commented we need to know more “about what teachers learn in these kinds of forums” (p176). Two critical elements are seen repeatedly in professional development studies and these elements can greatly facilitate and monitor teacher learning, namely reflection and in-
depth mentoring (Ball, 1996; Fishman et al., 2003; Stuessy & Metty, 2007). In addition, studies show that engaging teachers in communicating with their peers benefits for teacher understanding about student learning (Featherstone, Smith, Beasley, Corbin, & Shank, 1995). Sections below detail prior research in reflection and peer-exchange.

2.3.1 Fostering Teacher Learning Through Scaffolded Reflection

A substantial body of professional development literature has focused on reflective practice (Barnett & Coate, 2005; Schön, 1987) as a means of enabling the growth or development of teacher knowledge. 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 the moment as significant and ponder on possible changes for the next class or the next iteration of the lesson. “This form of reflection is immediate and significant for the action . . . the rethinking of some part of our knowing-in-action leading to on-the-spot experiment and further thinking” (Schön, 1987, p. 29). Schön found that as teachers engaged in new strategies, they reflected in action and developed new professional knowledge.

The teacher education literature comments on some salient general features of reflection which is seen as a form of cognition (McNamara, 1990; Schon, 1983). Reflective action was described by Dewey (1936), as a cyclical process in which teachers modify their own instruction based on reflection about what happens in their classrooms (Noffke & Brennan, 1988). Hatton & Smith, (1995) define three “characteristics of reflection-on-action” that are relevant to this study: (a) critical reflection, which entails thinking about one’s actions in relationship to others; (b)
dialogic reflection, which entails thinking about actions as a narrative; and (c) descriptive reflection, which entails thinking about actions and giving reasons for actions.

Through the process of reflection, teachers think about their classroom practices and question why some lessons are successful and why some are not (Raines & Shadow, 1995). However, there are some problems associated with reflection. Many teachers do not reflect as part of their regular routines (McNamara, 1990), they do not have time or the opportunity to develop this skill (McNamara, 1990), and exposing intimate thoughts is a high risk activity for teachers as it makes teachers vulnerable (Wilman & Niles, 1987). This study recognizes the flaws in reflective practice and develops a structure and approach to reflection that assists teachers in their knowledge development.

Designers of learning environments often build supports or “scaffolds” for reflection into tasks and materials by asking learners to discuss and reflect upon their experiences. Section 2.5, below, describes the research on scaffolding for student reflections, which is relevant to the pedagogical interventions used within this study (i.e., project-based learning). Scaffolding refers generally to a process where learners are supported with paper or technology-based prompts or tools that enable them to achieve some cognitive or intellectual task that might otherwise go ignored or be unachievable. While scaffolding will be discussed in detail below, it is important to note that most research involving teacher reflections relies on some form of scaffolding, either through paper journals, or computer-based reflection prompts (Slotta and Linn, 2009; Fishman et al, 2003). At the minimum, these scaffolds help teachers keep track of their notes and thoughts. However, if designed carefully, reflection prompts can help teachers focus on specific features from their activities that are of relevance to the research or professional development (Gerard, Tate, Chiu, Corliss & Linn, 2009).
This dissertation study employed scaffolded reflection as a constructivist intervention for teachers as they planned and enacted inquiry curriculum (specifically, project-based, technology-enhanced science lessons). Teacher were scaffolded to reflect on the specific pedagogy they used, technology implementation, and student learning of science concepts. In addition, scaffolded reflections were shared among peers, and still other reflections were written in collaboration, offering a richer understanding about student learning within the context of the teacher lesson plan and enactment. Teacher engagement in scaffolded reflection suggests a theoretical construct for knowledge development, where teachers are encouraged to actively reflect on their ideas and develop understandings, and these ideas become visible to themselves, their peers and mentors as a resource for further professional development.

2.3.2 Teacher Learning Through Peer Exchange

Building upon the principles of situated learning, Lave and Wenger (1991) established the notion of a community of practice (CoP), in which participants develop shared understandings in the course of engaging in a set of practices that characterize the community. For example, in a study of midwives and tailors, Lave and Wenger (1991) revealed the elaborate, complex, negotiated processes of individual and community knowledge development that centred around the disciplinary practices of those professions. Communities of practice are persistent, self-replicating, and evolving entities that are distinct from, and commonly extend beyond, formal organizational structures (Barab & Duffy, 2000; Brown & Duguid, 1991; Lave & Wenger, 1991). They are distinguished from other forms of community through patterns of shared discourse and norms of behaviour (Lave & Wenger, 1991).

As Palinscar et al. (1998) remarked, Lave and Wenger never expected the educational field to adopt CoP, as their original theory had no implications for the development of educational communities. However, CoP is used frequently in the context of improving teacher
professional development models (Davis & Sumara, 1997; Erickson, 1991; Mitchell, 1994). The notion of a teacher community suggests opportunities for social interaction, mutual dependence, and group identification, and connects these ideas to classroom practices (Westheimer & Kahne, 1993). Such an organization, should it ever be achieved, would certainly be reminiscent of a CoP, in which the knowledge of practice is both explicit and implicit (Palinscar et al., 1998). Scholars have suggested that if learning, thinking, and knowledge construction are inextricably connected to social contexts, providing opportunities for teachers to have meaningful deliberation, interaction, and reflection within a community of peers would nurture their practice and professional development (Palinscar et al., 1998).

Thus, the notion of a professional learning community for teachers suggests a promising approach for supporting teacher professional development, for example by assisting teachers in adopting new instructional or assessment practices within their classrooms. Some elements of a learning community have been suggested by prior research: (a) shared norms and values, (b) shared discussion and analysis of practice, (c) reflective dialogue, and (d) collaboration of ideas (Bowyer, Gerard, & Marx, 2009; Louis & Kruse, 1995). Technology scaffolds could be developed to serve the needs of such a community of practice—for example, to help make the characteristics of effective teacher professional development more visible and explicit (Schlager & Fusco, 2004).

There has been a good deal of research concerning the potential benefits of professional communities of practice for learning. By engaging in relevant occupational activities and then exchanging reflections with peers and mentors, individuals gain opportunities to become more competent practitioners (Schlager & Fusco, 2004). The Tapped In project (Schlager, Fusco, & Schank, 2002) offered a professional environment that was described as a network of practice (Brown & Duguid, 1991), a constellation of practices (Wenger, 1998), or a crossroads of
multiple educator communities. Tapped In demonstrates the value of online communities and the affordances that online communities offer. Online communities have potential for enhancing professional development for teachers by supporting their community of practice (Schlager & Fusco, 2004; Smylie, Allensworth, Greenberg, Harris, & Luppescu, 2001).

Through participation in a community of practice, teachers could receive support from peer networks, local administration, mentors and other outside experts. Unfortunately CoP is not the norm for teachers, and professional development programs tend to be disconnected from everyday practice, fragmented, and misaligned. Teachers typically lack any experience in professional exchanges with peers. Researchers have reported on the challenges of building a safe, comfortable learning environment for teachers. Grossman, Wineburg, and Woolworth (2000) reported that teachers are reticent to engage in critiquing the practice of their peers. Teachers also find it difficult to reflect on their own practice, because the process too personal and generally outside their professional character (Ball & Cohen, 1999). Moreover, teaching has long been understood by teachers and school leaders as having a culture of privacy (Little, 1993). Thus, while reflective exchanges within a community of peers have great potential for supporting teacher professional development, such exchanges would in themselves constitute a substantive change in teaching practice.

Prior research on teacher knowledge taken together with the notion of learning within a community of practice, underscores the importance of a practice-based approach to professional development. The next section describes approaches in teacher professional development that are deeply interconnected with practice.
2.4 Teacher Professional Development

According to Hargreaves (1992), the teacher is the ultimate key to educational change, and many researchers have argued that teachers should be the central component in educational reform (Cuban, 1990; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). An important goal of educational research is thus to help teachers improve their own understandings about learning and instruction so that they can ultimately be more effective. This research includes the prospect of helping teachers adopt research-based innovations and pedagogical approaches. Educational researchers have begun to examine teacher enactment of research-based science materials (Crawford, 2000; Roth, 1995; Tabak & Baumgartner, 2004). However, helping teachers adopt new practices in their curriculum design or enactment is a challenging process that involves substantial professional development and participation by several stakeholder groups (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Schneider, Krajcik, & Blumenfeld, 2005; Slotta, 2004; Slotta & Linn, 2009).

Based on the theoretical perspective of learning reviewed above, teachers’ adoption of new constructivist approaches will be governed by the sociocultural context of their own classroom enactments. Professional development models aimed at helping teachers implement new modes of instruction have had limited success because they tend to be detached from the direct context of the teacher’s classroom (Confrey, 1986; Howe, 2006). The following sections review some relevant professional development research, with a focus on the challenges that teachers face as they develop new knowledge and classroom practices.

2.4.1 Professional Development Programs and Approaches

Programs such as the Eisenhower Professional Development Program (Garet, Porter, Desimone, Birman, & Yoon, 2001) supported teachers as they developed knowledge and skills with specific subject-matter focus and improved their classroom teaching practices. Other
professional development programs such as the National College for School Leadership (NCSL) provide in-service training programs to help teachers be active and reflective in the process of change (Darling-Hammond, 1995). These programs are designed to provide opportunities for teachers to share what they know, discuss what they want to learn, and connect new concepts and strategies to their own unique contexts (Darling-Hammond & McLaughlin, 1995).

Other researchers have suggested that technology-based environments could help teachers as they begin to modify their classroom habits and develop new ones. Livingston and Condie (2004) evaluated an on-line, e-learning program called SCHOLAR to help teachers develop readiness and comfort in the use of ICT (information and communication technology) within their classroom. In the SCHOLAR program, there were induction events, seminars, and conferences to engage teachers in the strategies for implementation, but many teachers reported that they required more training (Condie & Livingston, 2007). The findings from the SCHOLAR studies suggested that, even with greater confidence in ICT skills, teachers were not able to use ICTs to their full potential in support of learning, in part due to the teachers’ fear that they would be replaced by computers (Fabry & Higgs, 1997; Livingston & Condie, 2004). In many studies, professional development separates teacher learning from student learning. The next professional development model tries to study professional development in the context of student learning.

Fishman and colleagues (2003) designed a professional learning model for teachers and an analytical framework that linked student learning to teacher learning. This professional development design incorporated the following: (a) content of professional development, (b) the strategies implemented, (c) the location of professional development, and (d) the media used. In this large-scale research study of middle school teachers, curriculum materials used constructivist principles. Using a framework of teacher reflection, classroom observations, and continuous student assessment to analyze teacher understanding about the science content and
student understanding, new pedagogy or strategies were discussed as part of the professional
development. In the next iteration, student learning improved and directly mapped onto the
changes in teacher knowledge.

Another example of a professional development program was that of the US National
Science Foundation, TELS (Technology Enhanced Learning in Science). TELS supported
teachers as they incorporated technology-based innovations within their science classes, engaged
in inquiry instruction, and adopted new evidence-based practices (Linn, Lee, Tinker, Husic, &
Chiu, 2006). TELS employed a targeted professional development model, in which teachers
were involved in customizing curriculum for their students with support from a mentor (Slotta,
2004; Spitulnik & Linn, 2006). TELS engaged teachers in two or more cycles of planning and
enacting the module, with later revisions based on evidence from student engagement within the
activity (Slotta, 2004; Spitulnik & Linn, 2006; Varma, 2006). The presence of a mentor was
identified as a key to any success that the teachers did experience (Slotta & Linn, 2009).
However, teachers did not generally succeed in adopting the reflective, evidence-based practices
called for by TELS (Slotta & Linn, 2009; Slotta, personal communication, December 2009). This
failure to engage in reflective practice is likely due to the fact that TELS lacked concurrent
support for teachers in their classrooms and did not engage them in reflection during the
instruction process.

The mentorship approach has been found to be an effective means of helping teachers
implement new methods, as the mentor can introduce new ideas and models effective strategies
(Peers, Diezmann, & Watters, 2003). Indeed, it has been noted that the mentor-teacher
relationship is based on the notion of cognitive apprenticeship (Brown et al., 1989; Davis &
Varma, 2008). The role of the mentor can vary from one of a distant online coach to a more
highly engaged process of modelling effective teaching practices or augmenting a teacher’s
instructional practices (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). However, it is difficult for mentors to offer direct support while teachers are engaged in their actual classroom instruction, which is when teacher knowledge is most likely to develop (i.e., in the context of classroom activities—see Ball & Cohen, 1999; Putnam & Borko, 2000).

Krajcik and Soloway (1998) have reminded us that teacher educators remember that teacher learning occurs mainly within the context of relevant professional practices:

Knowledge about teaching and practices related to this knowledge cannot be learned independently of the situation in which it will be used. Teachers cannot merely apply a set of predefined prescriptions, they need to plan and teach in order to tailor innovation to fit their unique circumstances, anticipating possible problems and devising strategies to deal with them. (p. 34)

Moreover, Yamagata-Lynch (2003) noted that the surrounding context of the institution of schooling is a strong, persistent influence on teachers’ practices: “The social structures prevalent in schools and classrooms organize the decision-making and the activities in which teachers choose to participate” (p. 2). Hence, consistent with the sociocultural perspective of learning and instruction, teacher knowledge development is deeply interconnected with legitimate teaching practices, which are embedded in the rich context of the classroom and school environment.

In general, professional development can “help teachers develop cohesive understanding about inquiry instruction by building on their existing ideas about student learning, technology, and the role of the instructor” (Slotta, 2004, p. 3). Professional development workshops provide effective learning opportunities for teachers if they include ongoing support that extends into the teacher’s enactment of new models (Guskey & Huberman, 1995; Slotta & Linn, 2009). Additionally, programs should build on the needs and interests of the teacher within the context of his or her classroom (Borko, Mayfield, Marion, Flexer, & Cumbo, 1997; Sandholtz, 2002). Moreover, from the perspective of collaborative learning, there remains an attractive potential for learning communities in which teachers share and reflect with peers. However, most teacher
professional development to date has neglected any specific mechanisms or tools for establishing collaborative environments (Van Driel, Verloop, & De Vos, 1998).

Most importantly, professional development models must take into account the process of teacher learning and the nature of teacher knowledge. Davis and Varma (2008, p. 97) have referred to Putnam and Borko’s (2000) statement that “teacher learning is situated within teachers’ own practice,” and reiterated that learning is a process of ongoing sense-making (Spillane, Reiser, & Reimer, 2002). Teachers must draw upon their own ideas about the content they teach and about student learning and appropriate pedagogy. In the process of acquiring new ideas (e.g., from continuing education courses, classroom experiences, professional development, or student work), they must reevaluate their pre-existing ideas and if necessary build their new ideas or link to them from their prior ones. Teachers rely on their knowledge flexibility throughout their instructional practice to plan and reflect in their real-time classroom interactions (Ball & Bass, 2003). Thus, the instructional strategy must be one that the teacher is empathetic to and has a belief in.

2.5 Inquiry-Based Instruction

2.5.1 Scaffolded Inquiry

This section reviews prior research concerned with inquiry-based instruction, particularly at the secondary science level, as teachers’ adoption of such instruction will be central to the current study. Research in instructional practices that are informed by constructivist perspectives has given rise to a broad category of instructional approaches collectively referred to as inquiry-based learning (Slotta & Linn, 2009). This approach is particularly common in the science education research literature, where inquiry has been identified as an effective means of engaging students and teachers in constructivist learning and constructivist-oriented teaching practices (Linn & Eylon, 2006; Quintana et al., 2004).
Inquiry curriculum typically includes a project-based focus (Krajcik, Slotta, et al., 2008) and seeks to incorporate social constructivist processes within its curriculum features, including the active construction of knowledge (Kolodner et al., 2003), working with data, experiments and argumentation (Sandoval & Reiser, 2004), critique and reflection (Slotta, 2004; Slotta & Linn, 2000), collaborative learning (Edelson, Gordin, & Pea, 1999) and discourse within a community of peers (Singer, Marx, Krajcik, & Clay-Chambers, 2000). The role for teachers within inquiry models is that of a guide or a mentor, enabling the students to discover, organize ideas, and explore their own questions. Teachers support students by modeling, providing examples, suggesting strategies for accomplishing tasks, giving feedback to students, and providing students with time for the revision of ideas (Hunt & Minstrell, 1994; Krajcik et al., 1998). Inquiry teaching generally is not easy for teachers to adopt, and support (e.g., mentoring or other scaffolds) is typically required to help teachers adopt their inquiry-based practices (Krajcik, Slotta, et al., 2008; Slotta, 2004).

Inquiry-based instruction often includes the notion of scaffolding as a means of supporting student-centred constructivist approaches. First introduced by Wood, Bruner, and Ross in 1976, the term scaffolding was used to describe the interaction between a tutor and a child as the child learned how to construct a wooden pyramidal puzzle. Wood et al. (1976) commented that scaffolding enabled a child or novice to achieve a goal that was just beyond their unassisted efforts. In general, scaffolding has now come to refer to any technological or procedural device whose purpose is to help students achieve some inquiry activity that might otherwise have been ignored or misdirected (e.g., reflection, peer review, or data analysis). Many researchers report on the use of scaffolds within their curricular approaches. For example, Quintana, Shin, Norris, and Soloway (2006) reported on a very broad scaffolding framework for
inquiry. Linn and Hsi (2000) introduced an instructional framework known as scaffolded knowledge integration.

Scaffolding helps to customize the constructive learning environment for each student while providing structure and guidance for the completion of inquiry activities. As the student becomes more successful, scaffolding should ultimately be faded, in order to promote autonomous achievement of the activities (Wood et al., 1976). Scaffolded inquiry instruction emphasizes student-centered activities, which often include open-ended activities and learning environments (Brown et al., 1989; Hannafin, Land, & Oliver, 1999; Jackson, Stratford, Krajcik, & Soloway, 1996; Linn, 1995). Such activities are meant to foster engagement in practices, such as occur in real inquiry communities like those of science and engineering (Quintana et al., 2006).

2.5.2 Inquiry-Based Science Instruction

Inquiry-based learning has played a significant role in science education research, particularly in the past two decades (Blumenfeld et al., 1991; Edelson et al., 1999; Keys & Bryan, 2001; Linn & Eylon, 2006; Slotta & Linn, 2009). Inquiry-based science instruction requires question-driven, open-ended processes that facilitate student-centred experiences about scientific problems (Linn & Eylon, 2006; Linn, Songer, & Eylon, 1996). Inquiry-based science curriculum typically engages students’ investigative skills (Schauble, Glaser, Duschl, Schulze, & John, 1995), model building strategies (Jackson et al., 1996; Wilensky & Resnick, 1999), and data synthesis (Linn, Bell, & Hsi, 1998; Wallace et al., 1998). Students who engage in such activities generate ideas in multiple contexts, develop a repertoire of ideas about phenomena, and reflect upon and develop their own understandings (Bjork, 1994, 1999; Chi, 1996; diSessa, 2000; Linn, Davis, & Bell, 2004; Scardamalia & Bereiter, 2006).
An inquiry-oriented approach to instruction can help students make connections between the normative ideas of science and personally relevant topics (Linn & Hsi, 2000). However, it can be quite challenging for science teachers to adopt such methods (Chiappetta & Adams, 2000; Lederman, 1992; Marx, Blumenfeld, Krajcik, & Soloway, 1997; Minstrel & van Zee, 2000). First, there is quite a range of inquiry-based approaches from prescriptive recipe experimental formats to completely open-ended discovery (Crawford, 2007; Keys & Bryan, 2001; Krajcik, McNeill, & Reiser, 2008). Secondly, teachers find it hard to address the children who have difficulty designing, performing, and conducting systematic scientific investigations (e.g., Krajcik et al., 1998; Schauble et al., 1995). As in any science instruction, it can be challenging to motivate students to perform investigations, as well as to develop and apply their scientific understanding (Keys & Bryan, 2001). Such challenges require science teachers to have an understanding of all the features for effective inquiry-based instruction, as well as to develop proactive implementation strategies. Many teachers have misconceptions about inquiry (Anderson, 2002) and do not take full advantage of this nontraditional, complex mode of instruction (Fradd & Lee, 1999). Indeed, Bybee (2000) has concluded that: “evidence indicates that science teaching is not now and never has been, in any significant way, centered in inquiry whether as content or as a technique” (p. 42).

2.5.3 Technology Scaffolds for Inquiry Curriculum

One research project that incorporated scaffolding within a technology-enhanced environment is that of BGuILE, the Biology Guided Inquiry Learning Environment (Sandoval & Reiser, 2004), which supported students in making scientific arguments in the context of population genetics. BGuILE presented students with authentic scientific mysteries—such as why many of the finches in the Galapagos Islands died during a specific period of drought (Sandoval & Reiser, 2004). In order to solve such a mystery, students have to explore extensive
data that was collected by real-world scientists and come up with a hypothesis about why some finches died while others survived. The Explanation Constructor tool (within BGuILE) prompts students to put together a sound genetics-based argument, scaffolding students to articulate their argument in a more explicit form than they would otherwise be able to do.

Other research programs have employed technology-based scaffolds to help students develop creative artefacts, arguments, or solutions to problems during inquiry-oriented projects. For example, the Web-based Inquiry Science Environment (WISE; Linn et al., 2004; Slotta, 2004) used a technology environment to scaffold students as they design solutions to personally relevant problems, debate scientific controversies, or critique arguments and evidence. WISE scaffolds include electronic journals that provide strategic prompts, argumentation tools, online peer exchanges, and simulation environments where students identify key scientific principles (Slotta & Linn, 2009).

Technology-based inquiry environments have the added advantage that they enable students to learn about technology itself (Linn, 2003). The science students of today need to know how to search databases, interpret models, and analyze and present data using digital resources (Linn, 2003). Learning environments typically consist of coherent curriculum and technologies that support students in learning, as well as teachers in instruction and assessment (Slotta & Linn, 2009). Once they learn how to take full advantage of such learning environments, teachers can even use students’ work to gain a sense of how their overall class is doing in the curriculum and to customize the next day’s instruction (Slotta, 2004; Slotta & Linn, 2009).

Still other forms of computer-mediated collaborative learning have been developed to facilitate student interactions and the acquisition of knowledge skills and attitudes as a knowledge community. For example, the Computer-Supported Intentional Learning Environment (CSILE), which subsequently became known as the Knowledge Forum
(Scardamalia & Bereiter, 1994), scaffolded students as they added new ideas to a collective repertoire, built on the ideas of peers, and made progress as a community in developing an understanding of science topics (Hewitt, 2005). Such computer-mediated communications can help students collaborate in a more structured, self-directed, and explicit manner (Koschmann, 1999), enhancing reflection and argumentation as the flow of ideas becomes more visible within the group (Scardamalia & Bereiter, 1994).

Many researchers have used technology to enhance and support inquiry-based science instruction. In the present study, technology provided will provide a persistent resource for teachers as they plan and enact an inquiry-based lesson, as well as a resource for their students (depending on teachers’ designs). The next section describes project-based learning—a particular form of inquiry-based instruction that is central to the present research—as it offers a well-defined and accessible model that can be implemented by teachers who are just beginning to explore inquiry.

2.5.4 Project-Based Learning

Project-based learning (sometimes referred to as PBL, and often misconstrued as problem-based learning because of the more common use of that initialism) involves learning by doing complex, challenging projects (Brown et al., 1989). Project-based learning is a type of inquiry-based approach in that it arose from constructivist principles (Blumenfeld et al., 1991; Cobb, 1994) and promotes interdisciplinary activities where students collaborate with their peers (Marx et al., 2004; Sawyer, 2006). Project-based learning is often carried out over extended periods of time (Laffey, Tupper, Musser, & Wedman, 1998), and the curriculum addresses specific content learning objectives (i.e., it isn’t simply a supplemental or capstone project). Through scaffolded investigations, students collaboratively and creatively investigate personally
relevant science problems (Krajcik & Blumenfeld, 2006; Krajcik et al., 1998; Krajcik, Czerniak, & Berger, 2002).

For teachers, project-based learning offers opportunities for formative assessment, feedback, and curriculum revisions (Barron et al., 1998). Ideally, teachers must play a role in supporting students and maintaining their motivation and thoughtfulness (Blumenfeld et al., 1991). One example of a project-based approach instruction is ThinkerTools Inquiry Curriculum (White & Frederiksen, 1998) in which students generated questioning, experimented with technology, and used real-life tools to formulate models and participate in metacognitive reflection about the science concept. Physics students in this study outperformed students learning by traditional means on qualitative real-world problems (White & Frederiksen, 1998). Another prominent example is that of the IQWST project (Krajcik, McNeill, & Reiser, 2008)—a 3-year middle school science curriculum designed by researchers from the University of Michigan and Northwestern University, together with the American Association for the Advancement of Science, to help students relate ideas across life, earth, and physical science. IQWST begins each project with a driving question and then engages students in scaffolded inquiry activities to help them address that question (Hug, Krajcik, & Marx, 2005).

Project-based activities often employ technology-enhanced materials (Linn, 2003; Quintana et al., 2004). For example, computer-based simulations allow students to explore systems and relationships (e.g., in global warming or molecular processes) that might otherwise be invisible. Despite the rapid development of technology-enhanced inquiry environments and the evidence that project-based learning is beneficial, these methods have been rather slow to appear within science classrooms. It is challenging for teachers to integrate such rich, contextual forms of instruction into their classroom practices, because it requires them to make substantive changes not only to their curriculum but also to their understanding of how students learn within
their instructional domain. This is essentially a matter of teacher knowledge development, which will be the focus of the next several sections of this review. Teacher knowledge and professional development are critical in helping teachers overcome the obstacles of integrating strategies such as project-based learning and technology-enhanced inquiry into their classrooms.

This dissertation will incorporate project-based instruction to guide teachers’ development of new inquiry-oriented (and technology enhanced) science lessons. The following criteria are common to most project-based learning approaches, and are drawn from a combination of papers cited above (e.g., Blumenfeld et al., 1991; Krajcik, McNeill, & Reiser, 2008; Krajcik, Slotta, et al., 2008): (a) the student task or project must involve real-world issues—or be personally relevant; (b) the project must pose a problem for students, and must offer choices or flexibility concerning how it should be addressed; (c) project-based work must be collaborative; and (d) students must create a culminating artefact that demonstrates their understanding of the central science topics. These criteria provided teacher participants with a clear description of project-based learning and served as a (detailed in Chapter 3) to help guide their lesson designs.

2.6 Summary

The prior research on inquiry and project-based learning in science suggest that this instructional approach offers an effective means of engaging students in constructivist learning activities. Such methods will also engage teachers in new kinds of pedagogical practices, which will serve to promote their own development of PCK. Arguments exist in the literature that teachers learn such knowledge primarily through engagement within legitimate professional practices, and that the constructivist perspective can help guide the design of learning activities for teachers as well (i.e., in the form of reflection and peer exchange).
CHAPTER 3:
METHODOLOGY

3.1 Methodological Overview

This research utilized an iterative design-based approach to examine teacher professional development within the rich context of a curriculum-design community, where secondary science teachers designed, enacted, and revised a technology-enhanced project-based lesson. Teachers’ lessons were designed according to a generic set of characteristics for project-based Learning (Blumenfeld et al., 1991; Laffey, Tupper, Musser, & Wedman, 1998) 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; Slotta, 2004). This study focuses on two primary forms of intervention in teachers’ development of PCK: scaffolded reflections and peer-exchange within a community.

Studying teacher activity within the complex learning environment of a science classroom requires a methodology that is flexible and adaptable. The methodology must provide evidence-based insights for the practitioner-audience (both the researcher and the teachers), provide formative feedback, and promote the advancement or elaboration of knowledge (e.g., plans, ideas or models) and practices (e.g., instructional strategies).

A strong effort was made within this study to maintain controlled conditions for the interventions (e.g., teachers were requested to post their reflections, which were structured using wiki pages; teachers were requested to attend community meetings) it was understood from the outset that an accommodating format for the research must be adopted, as the overall task demands of teaching are simply too challenging and unpredictable for any coercive methodology. Moreover, the research itself was somewhat formative, in the sense that the
primary researcher (herself a veteran teacher) was serving as a mentor to all teachers and was a participant within the community. Little prior research has been done on providing in-service support to a community of teachers. Hence, it was expected that the researcher would learn much in the early phases of the study and adapt all supports and processes through subsequent phases. A design research methodology is well suited to this context, as it allows for periodic adaptations or adjustments of the interventions as informed by the ongoing research.

3.1.2 Design-Based Research

This study employed a design research methodology to examine the development of teacher knowledge as teachers plan, enact, and revise a technology-enhanced project-based lesson. Design-based research (DBR) is an emerging methodology within the learning sciences that entails successive iterations of materials and interventions within naturalistic contexts such as schools and classrooms (Barab, 2006; Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Collins, 1992; Sandoval & Bell, 2004). Confrey (2006) describes this research as extended investigations and iterative applications for the study of learning in complex classroom environments. DBR responds to the challenges of developing controlled conditions for comparison studies within such environments. By carefully monitoring the impact of design features (e.g., curriculum elements) on important variables (e.g., student learning or teacher practices), it is possible to make informed revisions of the design, which can then be implemented to observe the impact of those design improvements on the same variables. As described by Cobb et al. (2003), “the designed context is subject to test and revision and the successive iterations that result play a role similar to that of systematic variations in experiment” (p. 9).

There has been substantial discussion and debate within the learning sciences literature concerning the efficacy and validity of design-based research (see the recent Cambridge
Handbook of the Learning Sciences, edited by Keith Sawyer, 2008, for many articles). Overall, it has gained wide recognition and respect as a methodology capable of responding to the complexity of the research domain while still preserving some capacity for empirical findings. However, DBR has been criticized for its focus on positive outcomes, its lack of separation between researcher and participants, and its reliance on research measures as a source of input into the design of research materials (Design Based Research Collective, 2003). In response, Barab and Squire (2004) argue that design-based studies can generate new theories and that DBR is appropriate for certain research contexts. Barab (2006) has noted that design-based methods have grown to allow for more rigorous empirical approaches. He advises that DBR should have the following: (a) assumptions and theories that are explicit, (b) continuous data collection that is relevant and connected to theory, and (c) multiple voices and accountability structurally embedded in the design.

A related approach known as co-design has been advanced by Roschelle and his colleagues (e.g., Roschelle, Penuel, & Shechtman, 2006) to define a rich form of collaboration between one or more teachers, one or more researchers, and members of other stakeholder groups (e.g., school administrators). In co-design, all members meet frequently throughout the design and implementation phases of the research, negotiating both the research goals as well as the teaching enactment goals. In short, the teacher is integrated into the research group, and the researcher becomes invested in the goals of teaching (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). While time intensive, co-design ensures that teachers gain an appreciation of the relevant theoretical ideas (e.g., project-based learning) while ensuring that researchers never lose sight of the logistic and pragmatic concerns of the classroom in which the innovation will be implemented. The approach also ensures that any innovation produced will be fully comprehended by the teachers, who will then accurately implement the design. The co-design
approach has proven successful in the creation of innovative technology-based curriculum (Roschelle et al., 2006; Slotta & Peters, 2008). Further, co-designed materials have been shown to promote student learning in science (Krajcik, Blumenfeld, Marx, & Soloway, 1994; Linn & Slotta, 2004; Pea, 2004; Quintana et al., 2004; Slotta, 2004), which is advantageous from any perspective. Co-design is complementary to design-based research in important ways so that as theories are developed and linked, the continuous cycles of learning, and the sharing of the theories, become relevant to researchers and practitioners alike (Design-Based Research Collective, 2003). Methods of documentation and the connections between research and practice are critical to design-based research. This has led many design-oriented researchers to focus on rich qualitative measures, including an emphasis on video recordings of classroom practices. Video offers a way to capture actions and interactions so that researchers can develop an understanding of the learning processes. With the iterative nature of design-based studies and appropriate use of co-design approaches to lesson design, it becomes evident that the data analysis of all the elements involved and all the relationship that could influence teacher knowledge development is very overwhelming.

The design-based research paradigm arose out of the need to merge aspects of human psychology, personal histories and experiences, and local contexts (Hoadley, 2004). Some defining characteristics include an emphasis on the intervention outcome, the blurring of the researcher-participant distinction, the sharing of results with participants, and, finally, the active following of “leads” or design ideas that emerge from in the various iterations (Hoadley, 2004). In the present study, for example, the researcher was deeply connected to the teachers’ planning, enacting, and revisions of lessons, and all interventions and materials were revised. The research reviewed teachers’ scaffolded reflections, lesson design revisions, patterns of actions, and community exchanges and intervened in appropriate manner to enhance the objectives.
This study employed a design-based approach for all interventions and materials, recognizing that it would be impossible to create suitable control conditions, and that formative improvements of materials were of value to investigate the positive impact of reflection and community. That is, if initial materials or approaches to engaging teachers were seen to be faulty or ineffective, the aims of this research would be better met by improving those materials accordingly. To that end, the study includes three distinct design phases, with each one adding a new level of progress in the design of the reflection materials and supports, as well as the structure and functionality of any mentoring and peer exchange.

3.2 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 the participants’ teaching experiences and subject expertise. Approximately seven of the nine teachers were experts in more than one science discipline, which is represented by the colour gradient in Figure 1. The colour that is lowest on any teacher’s bar represents the subject discipline that was the teacher’s earliest subject domain. For example, Bill was originally a biology teacher, with a strong background in plant physiology; as the years progressed, Bill became an expert in physics too and began to teach only physics.
The teachers were from five different schools located in a large urban city in North America and had a range of technology supports provided within their respective school settings. All participating schools had culturally diverse student populations. The teachers were selected for this study based on their interest in participating in the project, which was described to potential participants as involving a substantial (and unpaid) commitment in terms of planning and enacting technology-based inquiry lessons. For each teacher participant, a co-design process for the lesson was begun in partnership with myself, a doctoral student with 17 years of experience teaching in secondary science classes.

Three of the participants, Charlie, Frank, and Olga, taught at a private urban school (pseudonym: Science Academy) where students are highly motivated to achieve excellence in all topics of instruction. Of the three, Charlie was the most veteran, and the only one who could remain involved with this study through more than two iterations of the lesson planning and

* gradients indicate multiple domain expertise

**Figure 1.** Teacher-participants—years of experience and subject expertise
enactment. Charlie was very active within the school and was responsible for a large cultural variety show. In addition, he had experience with technology and had integrated technology (e.g., smart boards) into his prior instruction in physics as well as into other school administrative tasks (e.g., grading and communications with students).

Olga was a new faculty member at the Science Academy, who arrived with a good deal of international expertise with not-for-profit organizations. She was really interested in lessons that addressed real-world issues such as global climate change. During the duration of this study, Olga became ill and was ordered to take bed rest. She was still able to complete two iterations of her project lesson.

Frank was another young member of the Science Academy; he had a general biology and physical education degree. His experiences included a lot of extracurricular sports activities. Unfortunately, because Frank was only employed on a yearly contract, he was unable to continue teaching at the Science Academy and did not participate in a second iteration of his lesson planning and enactment.

Two participants, Alex and Placido, were teachers at another private, all-male school. The school put a great emphasis on athletics and also had high academic standards. Alex ran a number of sports activities, was an elite athlete himself, and had a great rapport with all the students and other teachers at the school. Alex was able to complete one iteration of lesson planning and enactment. Placido was a veteran at the school and had a familiar sense of all his peers and the students. He was a veteran member of the faculty, and although he suffered from substantive medical conditions, was also able to complete one iteration of lesson planning and enactment.

Bill and Daryl were colleagues at an urban public secondary school. Bill was a former department head of science at the school and had many years’ experience in teaching every
subject within the Ontario curriculum. At the time of recruitment to the study, he was heavily involved in a number of extracurricular activities including organizing all technical aspects of the school assemblies. Bill was able to carry out two iterations of lesson planning and enactment.

Daryl was a relatively new faculty member of the school and had limited experience as a teacher at the secondary level. He was very knowledgeable about science and biology as he had worked at a zoo for many years and had led informal programs in ecology. He was enthusiastic about teaching and was very active in coaching various sports within the school. Daryl was able to complete two iterations of lesson planning and enactment.

The last two participants were Merle and Maddie. They were colleagues at an urban public secondary school. Merle was the former department head of science at this school and had many years’ experience in teaching every science subject within the Ontario curriculum. At the time of recruitment to the study, she was switching to a new school that was housed in a science centre. Merle’s class taught gifted physics Grade 12 class. Merle was able to participate in two iterations of lesson planning and enactment. Maddie was a relatively new teacher of physics at her school, but she had experience teaching science at the secondary level. She was very engaged with the project and enjoyed learning about integrating technology into her class. Maddie was able to complete two iterations of lesson planning and enactment.

Table 2 outlines the background of the teacher participants, including years of experience and subject-domain expertise, educational background, and subjects taught. The participants vary considerably, which is well suited to this research as the sample provides an interesting and appropriate cross-section of novice to expert teachers. A cross-section of participants with wide experiences in this study is necessary to investigate teacher knowledge that is often attributed to number of years in the classroom.
Table 2
**Teacher-Participant Summary Information**

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Educational Background</th>
<th>Years of Teaching Experience</th>
<th>Subject Taught</th>
<th>Iterations in Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daryl</td>
<td>BSc/Biology</td>
<td>3</td>
<td>General Science</td>
<td>2</td>
</tr>
<tr>
<td>Charlie</td>
<td>BSc/Physics</td>
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<td>General Science/Physics</td>
<td>2</td>
</tr>
<tr>
<td>Bill</td>
<td>BSc/Biology</td>
<td>25</td>
<td>General Science/ Biology/Physics/Chemistry</td>
<td>2</td>
</tr>
<tr>
<td>Frank</td>
<td>BSc/Kinesiology</td>
<td>3</td>
<td>General Science</td>
<td>1</td>
</tr>
<tr>
<td>Maddie</td>
<td>BSc/Biology</td>
<td>5</td>
<td>General Science/Physics</td>
<td>2</td>
</tr>
<tr>
<td>Alex</td>
<td>BSc/Kinesiology</td>
<td>6</td>
<td>General Science</td>
<td>1</td>
</tr>
<tr>
<td>Placido</td>
<td>BSc/Animal Physiology</td>
<td>30</td>
<td>General Science/Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>Merle</td>
<td>BSc/Physics</td>
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<td>General Science/ Biology/Physics/Chemistry</td>
<td>2</td>
</tr>
<tr>
<td>Olga</td>
<td>BSc/Chemistry/MSc</td>
<td>3</td>
<td>General Science/Physics/Chemistry</td>
<td>2</td>
</tr>
</tbody>
</table>

3.3 Materials

3.3.1 Pre-survey and Interview Questions

In order to establish a measure of teachers’ background and pedagogical content knowledge, a pre-survey was designed that was administered to all teachers, followed by an interview that was administered for purposes of clarification and to better acquaint the teacher and the mentor-researcher. The following questions were a subset of 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?
4. What are your criteria for success and failures of projects?
These questions identified teachers’ understanding of project-based learning, authentic learning experiences, and reflective processes. A full list of the interview questions is provided in Appendix B, along with some sample responses.

3.3.2 Scaffolded Reflections in a Wiki Environment

In this study, a wiki served in several different capacities. First, it provided a technology scaffold for teachers’ reflections. Over the course of this research, the wiki pages and prompts were improved as a result of iterative refinement, and the teachers became increasingly skilled at using the wiki environment.

The wiki site supported teachers in their lesson design and reflection activities, and thus played a significant role in supporting socially constructed knowledge throughout this study. It enabled teachers and the mentor to make their knowledge visible to themselves and to other members of the community (see Figure 2).

A specialized wiki, with private pages for each teacher, was designed to support teacher reflections, lesson plans, and peer exchanges throughout this study. For each stage of the planning and enactment cycle, careful attention was paid to the development of reflection prompts.

The following reflection prompts (i.e., short, targeted questions) were asked 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?

The following reflection questions were asked during the lesson enactment:

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 setup during lesson?

The following reflection questions were asked 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?

These questions served to guide the teacher’s reflections, and supported the mentor’s efforts to help the teacher achieve a successful design (i.e., one that met the criteria of project-based learning and integrated technology) and engage in meaningful reflections. In successive design phases of the study, these reflection prompts were refined and were supported more effectively with the interview questions.

3.3.3 Lesson Planning Wiki

A wiki site was designed with scaffolds (in the form of headers and sub-headers) to support teachers as they designed their new technology-enhanced project-based lesson. Some categories from the wiki were (a) Determining topic, (b) Challenging for students?, and (c) How can technology help? During the lesson planning stage of each iteration, teachers worked closely with the mentor-researcher to complete the lesson plan template. They were provided with supportive tools and resources such as guidelines and sample lessons (see Appendix B).

These served to standardize lesson plans (i.e., with a set of common headers and sub-headers), and included specific prompts for all sections of the lesson plans.
3.3.4 Technology Tools for Teacher Lessons

Teacher-participants used various technologies for their lessons including productivity software (e.g., Microsoft Office, iMovie), visualization tools (e.g., cMap), social technologies (e.g., wikis), and interactive learning environments (e.g., WISE: The Web-based Inquiry Science Environment). Teachers used the technology tools as a way for the students to create digital artefacts. All teachers created a technology environment that was incorporated into their lesson designs (e.g., designed a wiki-based activity where students would collaboratively create and edit pages). The technology-based environment provided a view into students’ learning of the science concepts.

3.3.5 Teacher Community Website

In addition, the researcher developed a website using the iLife service from Apple Inc. to serve as a cover page for the community. This was done because websites remained more intuitively easy for teachers to find and navigate than wikis. Predominantly, the website simply provided links to important wiki pages, resources, examples of lessons, and contact information (see Figure 3). A sample of the materials from these websites is provided in Appendix A in the form of screen captures.
The online component of the community consisted of a website and a companion wiki site, developed to collect personal statements from teachers about their background and philosophy, as well as to collect details of lesson plans and shared reflections. The online community supported peer exchanges and reviews of lesson plans and discussions about enactments. Upon completing their lesson enactment, teachers were asked to provide an update of the lessons learned and the “things I hope to add to the lesson next time.” Teachers were asked to encourage questions of their peers and comment on their lesson plans.
3.4 Design

This study had three design phases in which successive improvements were made to the reflection and community materials, and procedures. The first phase introduced the task to four teachers who co-designed a technology-enhanced project-based lesson with myself, the mentor-researcher. These teachers then enacted the lesson and revised the lesson plan based on their experiences and observations. At four points within this process, teachers were asked to conduct structured reflections, using their personal wiki page: after the lesson design, during the enactments (twice), and after the lesson enactment. The community conditions within this first iteration could be described as limited, at best. This was partly due to the limited capacity of the researcher (i.e., to start up four teachers in a mentored relationship as well as establishing a cross-town collegial community). But also, because of the unfamiliar aspects of this guided design task, it made sense to hold off on establishing any explicit community condition until a subsequent phase. Still, the co-design process itself was quite social and included contributions from two researchers and a technology specialist, and could certainly (i.e., from an Activity Systems perspective) be considered as a community element. In fact, even if teachers had no support from the teacher-mentor during the lesson design phase of the lesson, we must recognize that teachers rarely conduct their practices within a complete vacuum of any community—as they are always within a school community of peers and students. This first design phase also had a relatively light reflection component, as the reflection prompts were somewhat open-ended.

Design Phase II, which began in the following school year, improved upon the reflection prompts with more connections to lesson planning and enactment and introduced an explicit dimension of peer exchange within the community (both online and face-to-face). The teachers first met as a community during this phase, with five new teachers being added to the established
group of four. At the first community meeting, the veteran teachers reviewed their experiences, shared their lesson plans as well as a few selected reflections, and discussed the challenges and opportunities of project-based learning. During this phase, which lasted one school year, all teachers met regularly with the mentor to co-design a technology-enhanced project-based lesson (or, in the case of the phase one veterans, to revise their existing plans). There were two community meetings held during this phase, as well as a new dimension of online peer exchange.

A third and final design phase began in the latter half of the second school year, during which the six teachers who stayed with this study were engaged in another cycle of lesson design revisions and re-enactment. In this phase, further improvements were made to the reflection prompts, this time following input from the teachers themselves, who had begun to establish a sense of identity as community. Reflections and lesson plans were shared more openly within the online community space, and were integrated into the community meetings. Community meetings focused on student achievement and issues of assessment within a project-based approach. The mentor continued to meet with teachers individually and supported their process of reflection, lesson design, and enactment. Figure 4 summarizes the overall design process (with more detail provided in the next section).
Figure 4. Design-based research: Overall design phases need to fix

### 3.5 Timeline and Summary of Schedule

The three design phases of this study occurred over three school years, beginning in November 2006, and finishing in June 2009. This schedule of activities was complex, as it required repeat visits to individual teachers’ classrooms as they designed and enacted their lesson, including video capture of the teachers’ enactment of lessons (with multiple teachers sometimes enacting their lessons at the same time). Table 3 details the timeline of data collection procedures.
Table 3

*Summary of Data Collection Procedures and Schedule*

<table>
<thead>
<tr>
<th>Modification</th>
<th>Design Phase I (n=4)</th>
<th>Design Phase II (N=9)</th>
<th>Design Phase III (N=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethics and Consent Forms (Boards, Teachers, and students)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher Activity</td>
<td>Ethics (Boards, Teachers, and students)</td>
<td>5 new science teachers joined the 4 original teachers Co-designed, enacted and redesigned project-based lesson</td>
<td>9 science teachers Continued with co-design, enactment and redesign project-based lesson</td>
</tr>
<tr>
<td>4 science teachers</td>
<td>Co-designed, enacted and redesigned project-based lesson</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaffolded Reflection Prompts</td>
<td>Simple reflections (open-ended)</td>
<td>Prompts targeted lesson planning and enactment</td>
<td>Prompts targeted lesson planning and enactment with specific focus on Project-Based Learning, Student Knowledge and Technology</td>
</tr>
<tr>
<td>Peer-Exchange</td>
<td>Limited exchange with only mentor-researcher (myself)</td>
<td>Community meeting (with researcher(s)— Lesson planning process, student exemplars shared</td>
<td>Community meeting (with researcher(s)— Reflections, lesson planning process and student exemplars shared with specific focus on Project-Based Learning, Student Knowledge and Technology</td>
</tr>
</tbody>
</table>


The research within the classes began in November 2006, with four teacher-participants. These teachers designed, enacted, and revised their lesson plan. By mid-April 2007, two of the teachers were able to enact a second run of their lesson design. In June of 2008, five new members were added to the community as the second phase began. Following a community meeting where the whole group of teachers planned, exchange ideas, and scheduled their lesson designs and enactments, the teachers then worked with the mentor on their lesson design. In December 2008, another community meeting was held; again, this was an exchange and sharing of lesson plans and enactment experiences. Teachers revised their lesson plan, and in some cases re-enacted them (in one case, for the fourth time). The final community meeting was held in June 2009.

3.6 Procedure

The following sections describe the procedure followed within each phase of this design-based study.

3.6.1 Design Phase I

The study began with four teacher-participants who were introduced to the concept of project-based learning and technology-based lessons. These teachers were interviewed and then asked to complete a questionnaire on their ideas about project-based learning and technology, reflection, and community. The details of the research (i.e., project-based lessons and technology integration), lesson planning, and student participation were outlined to the participants. Teachers then engaged in a wiki-based reflection about the topic of a lesson concept that would benefit from a project-based approach, as well as from the use of technology. The teachers then worked closely with a mentor to design a project-based lesson that integrated technology in a meaningful way. The project-based lesson had several requirements that were based on the
criteria defined in Chapter 2: students had to work collaboratively in groups and had to have some class time and support for their learning process; they had to produce a culminating digital artefact that would be assessed by the teacher; and the overall lesson had to address specific content expectations, rather than simply serving as a supplemental activity. These criteria were provided to the teachers as a checklist to be incorporated into elements of their lesson.

The technology component of the lesson was somewhat open-ended, with the one specific requirement that students needed to produce a final digital artefact. Digital media was seen as an important element of this activity for the teachers, who had limited understanding and experience of technology. The mentor provided teachers with a brief description of various technologies that could be used within their lesson plan, such as productivity software, (e.g., Microsoft Office), visualization tools (e.g., iMovie and GarageBand), social technologies (e.g., wikis or blogs), and interactive learning environments (e.g., WISE: The Web-based Inquiry Science Environment). The mentor then introduced teachers to the website and a wiki space and instructed them on how to use those technologies.

In the first design phase (November 2006-June 2007), reflective prompts and interviews were collected at the time of lesson design, once at the end of the classroom enactments (i.e., after assessment activities) and as the lesson were being redesigned. All classroom enactments of the lesson were captured by video. The mentor supported the teachers extensively as they enacted their new technology-enhanced project-based lessons.

Two of the teachers were able to complete a second cycle of planning and enactment within this iteration of the study. While all teachers had committed to participate in the study, only three of the initial four were able to continue into the second design phase. One teacher, Frank, was not able to continue in the study, as he did not have a science teaching position in the following year. 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, which marked the beginning of the second design phase.

3.6.2 Design Phase II

The second design phase began in late 2007, and in June 2008 a face-to-face community meeting that lasted for three-hours and included on-line activities. Of the nine teachers that were invited to this meeting, only five attended because of scheduling conflicts. New teachers to the community were able to see previous teachers’ work and exchange ideas about the success of their approaches. Teachers who were not able to attend were still able to contribute some of their prior work for review at the meeting, selected from their wiki-lesson planning and reflections. The meeting was divided into three segments: (a) introduction to a community of learners, (b) discussion of the previous year’s lesson plans and enactments, and (c) outlining of plans for the next term’s lesson plans and enactments.

The wiki lesson plans, reflections, and video capture allowed teachers from iteration 1 to effectively share their understanding of project-based learning, technology enhancements and student learning of science concepts. The sharing of lesson plans and revisions gave the new teachers a way to learn, as well as a way to plan and revise their own lesson plans more systematically. The sharing of wiki reflections was coordinated in the second hour of the meeting, when teachers were asked to break into groups of two or three (including researchers, who attended) to review and discuss the reflections that had been shared by participants from the first design phase.

The peer community meetings within this project included two components, online and face-to-face. The community meetings were designed to establish professional relationships through which the teachers exchanged ideas, shared their stories about student learning, and dialogued about their project-based enactment.
In August 2008 there was a second community meeting to help teachers plan and co-design their new lessons for the coming school year. After an initial icebreaker discussion (about how the summer had gone, and what progress had been made in lesson planning), the group conducted an activity that involved examining student artefacts from several of the teachers’ enactments in the previous design cycle. Then, teachers worked in pairs, with newcomers joining community veterans who had been part of the first design phase and had completed at least one cycle of planning and enactment wherever possible. The sharing of the lesson design and student final products helped to guide teacher discussions and keep a focus on the goal of student learning. Some of the new teachers were able to use lesson design or parts of the lesson design from the veteran community members. In other cases, teachers were able to see how veteran teachers had created their lessons, then work with the mentor to develop their lesson ideas more fully.

During this second design cycle, teachers benefited from an augmented set of wiki-reflection prompts as they developed and enacted their project-based lesson. The classroom enactments were again videotaped in order to document the activity patterns within the classroom. Student learning was also examined as a source of evidence about a teacher enactment of their lesson.

This was a shorter design cycle than the other two, lasting only four months (one school semester). In part, this is because the teachers had begun to establish a stronger community and had recognized among themselves some changes that would help the online reflections and exchanges. At the end of this cycle (in December 2008), a community meeting was held with four main components: (a) sharing of reflections (b) exchange of lesson plans and enactment experiences; (c) sharing of student digital artefacts, and (d) exchange of new plans for the next term (third design phase).
3.6.3 Design Phase III

The final iteration began in January 2009, with six teachers returning as seasoned experts to the wiki-technology and project-based lessons. During this iteration, reflections were collected from teachers before, during, and after the enactments, and feedback to students became a greater focus for the teachers. The teachers began to look more critically at their students’ progress in the project-based lessons and were able to give immediate feedback based on what they saw in the online environments. During this iteration, the wiki was moved to a new platform that was seen as more permanent (i.e., open source and easy access) and available to them after the research project was over. This was important, as the teachers needed to make sure they had a way to continue their project-based lessons after the research study had concluded.

The final face-to-face community meeting (June 2009) (with online component) allowed teachers to share their experiences once more in a structured way, using the wiki site. The meeting was again segmented into the following components: (a) community reflection sharing, (b) exchange of lesson plans and enactment experiences, and (c) sharing of student digital artefacts produced during this iteration. As this was seen as the final community meeting, the process of the teachers’ work, their own learning, and examples from students’ work were highlighted.
3.7 Data Sources and Measures

A large corpus of qualitative data was collected from a variety of sources over a three year time period, including wiki reflections, lesson plans, interviews, student artefacts, observations and video of teacher enactments, and video of face-to-face community interaction.

Given such extensive, rich and contextual data sources, a largely qualitative and pragmatic approach was required to interpret the “actions, situations, and consequences” (Creswell, 2007, p 10) that occurred throughout the study. This was achieved through the development of coding schemes to measure different qualitative dimensions of the practices of lesson planning and lesson enactment (described below). By using such a process, it was possible to measure the impact of reflection and peer exchange on teacher knowledge development. The following paragraphs provide details about each of the data sources used within this research. Further details about the analysis are provided in the next section.

3.7.1 Teacher Scaffolded Reflections

These were in the form of responses to carefully designed wiki template pages. There two sets of reflections, one to address the lesson planning activity and the other to address the enactment activity. Teachers reflected during and after lesson planning for 1 hour and then, during and after their lesson enactment, for a total of approximately 2 hours. There were usually 3-4 days of enactment, and therefore there were usually 3 enactment reflections. Over the course of the 3-year study, more than 10,000 pages of wiki reflections were generated by teachers and mentor. These provided a rich source information about project-based instruction, technology implementation, student learning and about the teachers themselves.

3.7.2 Teacher Lesson Plans

These were in the form of a wiki-template that captured different aspects of the lesson design. Each teacher completed a lesson plan outline using the template, and then moved his/her
ideas into a student activity wiki template and other technology-enhanced environments (e.g., WISE). The lesson plan brainstorming and design took place over several days and was audiotaped. There were approximately 2 lesson plans designed and revised per teacher for a total of 18 lesson plans. This became a source of information about the process of the co-design process, project-based and inquiry-based instructional understanding and technology tools used for the lesson.

3.7.3 Online Peer Exchanges

These were in the form of responses to predesigned wiki template pages. The wiki pages scaffolded the community exchanges based on three themes: (a) project-based learning, (b) technology and (c) student learning. There were two broad categories for online activity: (a) lesson planning and enactment; and (b) reflection. Below is a screen capture of the front segment of the online peer exchange. There were approximately 30 or 40 wiki responses from the community within these pages, which provided a data source concerning community participation and community influence on lesson design and enactment.

Figure 5. Online peer exchange screen capture: Front page
3.7.4 Video of Face-to-Face Community Interaction

All community meetings were videotaped and transcribed. These four hour meetings were used to measure community participation and influence in the community. They also provided a way to follow teacher knowledge as it passed from community to individuals.

3.7.5 Video Capture of Lesson Enactment

The video of lesson enactment of all teachers provided a rich understanding of all the interactions that occurred within the classroom. The enactment was assessed on project-based lesson criteria for small group and large group interactions. There were approximately 4 hours of videotape for each teacher enactment of the whole project-based lesson. Six teachers had two iterations of planning and enactment, and three teachers had one iteration, for total of 36 hours (approximately) of video footage.

3.7.6 Field Notes

Field notes were taken by the researcher at all stages of data collection. These notes served to highlight activities, themes and ideas that were relevant to the study. It gave a chronological understanding of this three year study. Four books of field notes were written.
3.7.7 Student-Generated Artefacts

Students’ final products from the project-based lesson were also collected as a secondary data source, to support the coding of lesson enactment. They provided evidence of the process of project-based activity.

3.8 Analysis Plan

There were two forms of analysis within this study. The first form involved analyzing the lesson planning and enactment activities. Two coding schemes were developed for that stage to address the quality of teacher activities, knowledge, reflections, and community participation. These coding schemes were inspired by an Activity Systems perspective (Greenhow & Belbas, 2007) as detailed below. The second form of analysis involved studying the videotape of the enactment of two teachers’ lessons. This analysis adapted a video coding established by Stuessy (2005) in order to capture the patterns of interaction between teachers and students. It is used primarily as a supportive analysis to illustrate the classroom dynamics within those two teachers’ lesson enactments. The following sections will outline the two forms of analysis.

3.8.1 Analysis A: Coding Lesson Planning and Enactment-Activity Systems Approach

As described above in Chapter 2, several theoretical traditions have embraced activities as a basis for understanding human engagement and learning, including that of situated cognition (e.g., Lave & Wenger, 1991), and Cultural Historical Activity Theory, also known as CHAT (Engeström, 1987; Leontiev, 1978). The CHAT perspective, while outside the scope of this dissertation, adopts an ecological perspective that examines the “viewpoints and the conceptualization of the interplay between systems and the adaptive transformation of systems across time” (Gay & Hembrooke, 2004, p 10). The Activity System consists of an individual or group engaged in patterns of activities as mediated by rules, tools, community, and division of labour. CHAT is usually associated with anthropological, ethnographic, and other sociocultural
approaches, but is also relevant to the learning sciences because of its focus on “dynamic change through participation in activities, tool mediation, and social construction of meaning” (Gay & Hembrooke, 2004, p 4). In particular, the notion of activity systems is appropriate for understanding relationships, capturing data sets, and systematically analyzing data that is situated within the rich context of a classroom.

CHAT has formalized activity systems in the form of an activity triangle that captures the complex array of elements described above (i.e., rules, tools, community engagement, etc.—see Figure 7). For example, a teacher’s lesson planning may be thought of as an activity system, with clear subject (the teacher), object (the lesson plan), rules (constraints of school systems, project-based lesson criteria) and even influences of community. This approach to capturing complex teaching practices as activity systems is compelling, as it would otherwise be quite difficult to capture the diffuse activities of lesson planning or enactment. Teachers ordinarily plan their lesson across a complex array of activities that happen interspersed with other activities and objectives: from grading papers to riding the bus to reading the newspaper. The activity triangle allows us to clearly describe such embedded and convoluted activities in terms of their constituent rules, tools, communities, and collaborations, which will be very helpful to analysis.

![Activity Triangle Diagram](image)

*Figure 7. Engeström’s Activity System (1987)*
An activity system perspective thus allows a way to operationalize the elements of teacher knowledge development that are contextualized within patterns of classroom practice. The activity system construct poses a framework for the analysis of dynamic and evolving forms of knowledge and human interaction that characterize teacher professional development (Barab & Squire, 2004; Engeström, 1993; Mwanza, 2002; Nardi, 1996). While PCK is traditionally seen as a cognitive, internal structure, an activity systems perspective allows for an interpretation of PCK as a knowledge construct that develops through teachers’ engagement in relevant practices (e.g., lesson planning and enactment, or discussions with peers and mentors). Such practices cannot be learned from textbooks nor any teacher preparation programs, because the learning depends upon engagement in specific activities. Thus, teacher knowledge development can be interpreted as an internalization of activity patterns, or an ongoing redistribution of the external and internal components of an activity (Kaptelinin & Nardi, 2006).

Recently, some researchers have begun to adapt the Activity System formalism as a means of capturing the complexity of learning and instruction. For example, activity-oriented design-based methodology (AODM) has been advanced as a hybrid methodology that combines design-based research and activity theory to help develop understandings about practice and knowledge in tandem (Barab, 2006; Greenhow & Belbas, 2007; Mwanza, 2002). While this study does not apply AODM specifically, it will borrow from one of its primary tools, namely the population of activity triangles to capture the elements of an activity system of interest. Table 4 shows the AT Mapping Tool developed by Greenhow and Belbas (2007)—which essentially guides the researcher to map an activity system onto the AT formalism.
Table 4

A Coding Tool, with Triangle Nodes Related to Specific Questions

<table>
<thead>
<tr>
<th>Step</th>
<th>Node</th>
<th>Characteristic prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Activity of interest</td>
<td>What sort of activity am I interested in?</td>
</tr>
<tr>
<td>2</td>
<td>Objective</td>
<td>Why is the task taking place?</td>
</tr>
<tr>
<td>3</td>
<td>Subjects</td>
<td>Who is involved in carrying out the activity?</td>
</tr>
<tr>
<td>4</td>
<td>Tools</td>
<td>What means are the subjects carrying out the activity?</td>
</tr>
<tr>
<td>5</td>
<td>Rules and regulations</td>
<td>Are there cultural norms, rules, and regulations governing the performance of the activity?</td>
</tr>
<tr>
<td>6</td>
<td>Division of labour</td>
<td>Who is responsible for what, and how are the roles organized?</td>
</tr>
<tr>
<td>7</td>
<td>Community</td>
<td>What is the environment in which this activity is carried out?</td>
</tr>
<tr>
<td>8</td>
<td>Outcome</td>
<td>What is the desired OUTCOME from the activity?</td>
</tr>
</tbody>
</table>

*Note.* From Greenhow & Belbas, 2007, p. 372

This study applied such an approach, in the interest of developing two coding schemes that would allow analysis of the various elements within the activity systems of (a) lesson planning and (b) lesson enactment, respectively. In essence, it borrows the AT formalism as a way of mapping the various data sources collected onto important dimensions of the teaching practices. In representing lesson planning, for example, the lesson goals, connections to science and to student ideas, project-based activities, reflections, interviews, and field notes would all be taken into account as part of the activity system. The coding schemes for lesson planning and enactment assisted in the understanding of teachers’ knowledge development across iterations (i.e., of planning and enactment) and also provided a reference for the comparison of teacher-participants. Tables 5 and 6 show how the mapping tool presented in Greenhow and Belbas (2007) was applied to the lesson planning and enactment activities, respectively.

The nodes of the triangle (see Tables 5 and 6) connected with the literature on project-based learning, professional development and constructivism. Critical aspects of project-based learning, such as small group interaction, or professional development aspects of identifying teacher prior knowledge become the node items for this thesis. The questions asked about the
nodes helped understand relationships within the data collected and helped define the activities of lesson planning and enactment.

Table 5

Eight Steps Relating Activity Triangle Nodes to Lesson Planning

<table>
<thead>
<tr>
<th>Step</th>
<th>Node</th>
<th>Question to ask</th>
<th>Node of triangle PK/PBL thesis</th>
</tr>
</thead>
</table>
| 1.   | Activity of interest | What sort of activity am I interested in? | Teacher designing a technology-enhanced project-based science lesson  
Technology embedded into lesson design  
Routines in the classroom seen, use of PBL index, reflection, revision, and community collaboration |
| 2.   | Objective | Why is the task taking place? | Design of effective lessons (plan), integrating PBL, allows for optimal student learning for the specific content domain; integrating technology effectively |
| 3.   | Subjects | Who is involved in carrying out the activity? | Science teachers (with 3–25 years of experience)  
Science teachers PCK (prior knowledge)  
Community of science teachers (network) |
| 4.   | Tools | What means are the subjects carrying out the activity? | Wiki lesson plans; Wiki reflections, interviews (prior to lesson plan design and before enactment)  
Student artefacts/student templates  
Community scripts |
| 5.   | Rules and Regulations | Are their cultural norms, rules, and regulations governing the performance of the activity? | School schedules and rules  
Student activity (i.e., logistics: class size, PBL index)  
Classroom determinants (dynamics, levels of abilities)  
Technology limitations (e.g., Google, YouTube, Video, PPT, and wiki use) |
| 6.   | Division of labour | Who is responsible for what, and how are the roles organized? | Teacher: lesson plans;  
Mentor roles within the lesson plan  
Community involvement in lesson plan  
Students completion of activity; artefact |
| 7.   | Community | What is the environment in which this activity is carried out? | Teacher-student community in the class (and in some cases on wiki—online environment)  
Teacher-mentor (researcher) interviews, wiki reflections, lesson design  
Teacher-peers; wiki site, website (interface) scripts and face-to-face brainstorming and sharing of ideas |
| 8.   | Outcome | What is the desired OUTCOME from the activity? | PBL science technology-enhanced lesson  
Increase in students learning science |
### Table 6
*Eight Steps Relating Activity Triangle Nodes to Lesson Enactment*

<table>
<thead>
<tr>
<th>Step</th>
<th>Node</th>
<th>Question to ask</th>
<th>Node of triangle PCK/PBL thesis</th>
</tr>
</thead>
</table>
| 1.   | Activity of Interest | What sort of activity am I interested in? | Teacher implementing a technology-enhanced project-based science lesson  
Technology embedded/use of into lesson design routines in the classroom seen, use of PBL index, reflection, revision, and community collaboration  
Student learning indicated through enactment |
| 2.   | Objective | Why is the task taking place? | Enacting an effective lesson, integrating PBL, allows for optimal student learning for the specific content domain (science) |
| 3.   | Subjects | Who is involved in carrying out the activity? | Science teachers (with 3–25 years of experience)  
Science teachers PCK (prior knowledge)  
Community of science teachers (network) |
| 4.   | Tools | What means are the subjects carrying out the activity? | Wiki lesson plans  
Wiki enactment reflections, interviews (prior to lesson plan design and before enactment)  
Use of technology—to understand student work; collaborative aspects of group work  
Student artefacts/student templates  
Community scripts |
| 5.   | Rules and Regulations | Are their cultural norms, rules, and regulations governing the performance of the activity? | School schedules and rules  
Use of community  
Reflection scaffolding—wiki/interview- for teacher  
Student activity (i.e., logistics—class size, PBL index; assessment for student learning)  
Classroom determinants (dynamics, levels of abilities, etc.)  
Technology limitations (Google, YouTube, video, PPT, and wiki use, etc.) |
| 6.   | Division of labour | Who is responsible for what, and how are the roles organized? | Teacher: taught lesson plans; reflection; created student assessment  
Mentor roles within the enactment (i.e., tech help; Community involvement in lesson plan  
Students completion of activity; artefact |
| 7.   | Community | What environment is this activity being carried out in? | Teacher-Student community in the class (and in some cases on wiki—on-line environment)  
Teacher-mentor (researcher): interviews, wiki reflections, lesson design  
Teacher: peers; wiki-site, web site (interface) scripts and face-to-face brainstorming and sharing of ideas |
| 8.   | Outcome | What is the desired OUTCOME from the activity? | PBL: science technology-enhanced lesson  
Increase in students learning science |

*Note. Tool 2; Greenhow and Belbas, 2007*
Based on these tools, two coding schemes were developed that mapped the existing data sources onto the activity system nodes. These coding schemes, shown in Tables 7 and 8, serve to capture the six nodes of the activity system triangle, using all available data sources. For each node, one or more codes were established that corresponded to specific elements or measures. For example, the object of the lesson plan (which, according to Table 5, is concerned with developing an effective project-based lesson plan) consists of eight distinct codes or elements that are related to this node of the triangle (e.g., Does the lesson topic connect to existing student ideas? Does it engage the student actively? Is there an explicit role for the teacher? (See Table 5) Each of these elements was assigned a score, according to a rubric that was developed to represent a range of achievement from 1 (low) to 3 (high) on that particular measure. Rubrics for Tables 5 and 6 are provided in Appendix D.

This approach blends a content analysis method such as that reported by Slotta (2004); Linn, Lee, Tinker, Husic, & Chiu (2006); or Liu, Lee, Hofstetter, & Linn (2008), with an activity-based design method (e.g., Greenhow & Belbas, 2007). It is important to recognize that, while the coding method is inspired by an activity-oriented perspective, it does not offer a comprehensive account of all nodes within the respective activity systems of lesson planning or lesson enactment. The theoretical and methodological traditions of cultural historical activity theory and even design-oriented activity-based research typically place a greater emphasis on understanding the nuances of all nodes in the activity systems. Within the Rules or Tools category, for example, there may be many guiding documents, materials, local conventions, or even personal habits that played a great influence in how these teachers planned or enacted a lesson. The coding method developed here does not deny that such a rich account of all elements within the activity systems would be of value. However, the coding used in this study seeks to abstract these elements to some extent, as they pertain specifically to the domain of project-based
learning, and map them onto the available data sources in order to support a valid, reliable method of coding and analysis.

Once developed, the coding scheme can be applied to a range of different questions. For example, the Subject node of the activity triangle generally refers to the teacher, including any PCK that he or she might bring to bear on the planning and enactment activities. If, over the course of two or more iterations of lesson planning, the Object score of a teacher’s coding scheme improves (i.e., improved lesson plans) then if the Subject score also improves, it could be inferred that better lesson planning corresponds to improved PCK. Of course, this is not a strong inference, but the coding scheme approach ultimately does serve to connect teacher PCK (as the Subject of the triangles) to the wider activity system, thereby allowing an investigation of the impact of the reflection and peer exchange interventions.
### Table 7
**Coding Scheme Developed for Lesson Planning, Connecting Available Data Sources (Elements) to Activity System Nodes**

<table>
<thead>
<tr>
<th>Activity Node</th>
<th>Element</th>
<th>Score (1–3)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>Selection or choice of content (PCK)</td>
<td></td>
<td>What reasoning does teacher give for using this particular content-concept for this project work (PBL)?</td>
</tr>
<tr>
<td></td>
<td>Subject bound to the strategy</td>
<td></td>
<td>What student learning of science is directly (integrated into) related to this pedagogy (PBL)?</td>
</tr>
<tr>
<td></td>
<td>TPCK—understanding of technology and use of it to improve the project design</td>
<td></td>
<td>What reasoning or demonstration within the lesson plan does teacher give about the use of technology either to help the science content or help the project process?</td>
</tr>
<tr>
<td>Object (based on project-based index)</td>
<td>Connecting to student ideas</td>
<td>How does the lesson plan connect to student ideas (addressing of prior knowledge)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inquiry-based project; exposes students to relevant ideas</td>
<td>How does the lesson make the assignment (lesson) more relevant to everyday life (i.e., practical and authentic)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Building on student understanding</td>
<td>How does the lesson plan help students to construct new knowledge (ideas) from their old knowledge, i.e., use of mind maps, concept maps, brainstorming, allowing for the free expression of their own thoughts connecting to the project?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Active student involvement in the process</td>
<td>How does the lesson plan show teacher involve the student in the process of the project (teacher designs student peer-feedback component)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teacher facilitation of project</td>
<td>How does the lesson plan incorporate specific scripts and roles for teacher (him-/herself) in the project? (Outlines the areas in which teacher input is required; teacher plays a role in the process component of the lesson)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assessment of the PBL-project</td>
<td>How does lesson plan indicate assessment components of the project (and check points for addressing student learning; possible connections to revision of lessons; or adjustment to lessons)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science concept taught</td>
<td>How does the lesson plan address science concept taught through PBL—is it supplementary or is a deeper science content?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type of technology (video; wiki, PPT, etc.,)</td>
<td>What type of technology chosen and reason behind choice within the lesson plan? How did they use the tool (describe the use of the tool)?</td>
<td></td>
</tr>
<tr>
<td>Rule/Tool</td>
<td>Able to articulate teacher-learning prior to enactment (reflection pre-enactment) metacognition</td>
<td>How does the teacher use the evidence of the lesson construction as a way to see student learning (challenges), TPCK, and problems with logistics? Did teacher reflect as requested and were they thoughtful?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Able to articulate student learning prior to enactment (2nd X) reflection</td>
<td>How does teacher recognize student learning before enactment and the importance of the enactment?</td>
<td></td>
</tr>
</tbody>
</table>

*(Table 7 continues)*
<table>
<thead>
<tr>
<th>Activity Node</th>
<th>Element</th>
<th>Score (1-3)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Able to articulate teacher-learning prior to enactment (2nd X reflection pre-enactment) metacognition</td>
<td></td>
<td>How did teacher use the evidence of the lesson construction (after enactment) as a way to see student learning (challenges), TPCK, and problems with logistics? What things (evidence) happened that prompted changes in the lesson plan?</td>
</tr>
<tr>
<td>Division of labour &amp; community</td>
<td>Interaction of mentor (or emerging leader) or community</td>
<td></td>
<td>How productive was the mentor in the lesson design? How heavy was the mentor’s role in the process? Did the teacher use mentor’s ideas and make it his or her own?</td>
</tr>
<tr>
<td></td>
<td>Influence of community</td>
<td></td>
<td>How did the community (peers) influence the teacher’s lesson plan?</td>
</tr>
<tr>
<td></td>
<td><strong>Total and Comments</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 8**

*Coding Scheme Developed for Lesson Enactment, Connecting Available Data Sources (Elements) to Activity System Nodes*

<table>
<thead>
<tr>
<th>Activity Node</th>
<th>Element</th>
<th>Score (1-3)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>Setting the context of the lesson (explicit instruction)</td>
<td></td>
<td>What reasoning does teacher explicitly give the students for doing this particular content-concept for this project work (PBL)? Clear instructions (aim of PBL seen)</td>
</tr>
<tr>
<td></td>
<td>Ownership of the lesson (comfort level)</td>
<td></td>
<td>How does teacher work through the elements of the lesson? What are some of the stumbling blocks? Does the teacher give examples for their project expectations?</td>
</tr>
<tr>
<td></td>
<td>TPCK: explain and demonstrate technology and use of it to improve the project design</td>
<td></td>
<td>How does the teacher explain the use of the technology within the lesson plan—does teacher demonstrate the use of technology either to help the science content or help the project process?</td>
</tr>
<tr>
<td></td>
<td>Capable of addressing the fluidity of the lesson *</td>
<td></td>
<td>How does teacher pace the lesson and gage student working through the lesson?</td>
</tr>
<tr>
<td></td>
<td>Small group Interactions</td>
<td></td>
<td>How does teacher create and establish the group work/collaborative work?</td>
</tr>
<tr>
<td>Object (based on PBL index)</td>
<td>Teacher makes connection to student ideas during class</td>
<td></td>
<td>How does teacher connect to student ideas during class (addressing of prior knowledge)?</td>
</tr>
<tr>
<td></td>
<td>Inquiry-based project; exposes students to relevant ideas to themselves or others</td>
<td></td>
<td>What does the teacher do/examples they use in class to make the lesson more relevant to everyday life (i.e., practical and authentic)?</td>
</tr>
<tr>
<td></td>
<td>Building on student understanding within the class</td>
<td></td>
<td>What do teachers engage in with students to build on their understanding? Questioning? Examples? Metaphors? Drawings? Other, e.g., go to this resource/website?</td>
</tr>
<tr>
<td></td>
<td>Enables planned student activities (collaborations)</td>
<td></td>
<td>How does the teacher involve the student in the process of the project? What language do teachers use to encourage collaborations? How do they ensure that this occurs?</td>
</tr>
<tr>
<td></td>
<td>Teacher achieves the objectives for teacher from lesson plan (walking around, asks questions)</td>
<td></td>
<td>How does the teacher design specific scripts and roles for him/herself in the project? (Outlines the areas in which teacher input is required; teacher plays a role in the process component of the lesson)</td>
</tr>
<tr>
<td></td>
<td>Teachers implements planned assessment</td>
<td></td>
<td>How does the teacher use the assessments structured within the lesson plan? How does this feed back into the lesson enactment?</td>
</tr>
<tr>
<td></td>
<td>Science concept taught (specific lecture)</td>
<td></td>
<td>What types of science emphasis does the teacher engage in during the lesson? Does the teacher teach a mini-concept lesson to SGI or does the teacher teach to larger class?</td>
</tr>
</tbody>
</table>
### Table 8. (continued)

<table>
<thead>
<tr>
<th>Activity Node</th>
<th>Element</th>
<th>Score (1-3)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Added to lesson plan on the “fly” (deepen the PBL aspects); as well as</td>
<td></td>
<td>What types of conversations does the teacher have with students to enhance the project? What types of additional structure does the teacher put into place for the lesson (as the lesson proceeds)?</td>
</tr>
<tr>
<td></td>
<td>addressing unexpected (real time) *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type of technology chosen for the lesson (video, wiki, PPT, projector)</td>
<td></td>
<td>How did they use the tool within their class?</td>
</tr>
<tr>
<td></td>
<td>The lesson plan used within the lesson</td>
<td></td>
<td>How many times did the teacher refer to the lesson plan? How did they implement the lesson?</td>
</tr>
<tr>
<td>Tool/rule</td>
<td>Teacher reflects on enactment</td>
<td></td>
<td>How productive was the reflection? Did the teacher adjust or readjust the lesson plan based on the actions from the class?</td>
</tr>
<tr>
<td></td>
<td>Teacher reflects on student learning through the lesson enactment.</td>
<td></td>
<td>How does teacher recognize student learning during enactment and the importance of the learning enactment?</td>
</tr>
<tr>
<td></td>
<td>Able to demonstrate after the lesson—how they would change—during the</td>
<td></td>
<td>How did teacher use the evidence of the enactment to help enact the lesson the next time? How did specific with technology, e.g., wiki site, help with the lesson enactment?</td>
</tr>
<tr>
<td></td>
<td>lesson (i.e., examples of change because of the reflection)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Div. of Labour &amp;</td>
<td>Teacher uses community ideas in enactment</td>
<td></td>
<td>How does the teacher use community advice within delivery of the lesson?</td>
</tr>
<tr>
<td>Community</td>
<td>Influence of community</td>
<td></td>
<td>How did the community (peers) influence the teacher’s enactment revisions (lesson planning script)?</td>
</tr>
<tr>
<td>Total and Comments</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.8.2 Analysis B: Video Analysis

The action patterns that occur within a teacher’s classroom enactments are important to our understanding of their pedagogical content knowledge. Many researchers have noted the opportunities provided by inquiry-oriented instruction for teachers to engage in deep exchanges with individual or small groups of students (e.g., Krajcik & Blumenfeld, 2006; Slotta, 2004; Penuel et al., 2007). Project-based learning is no exception to this, as teachers are freed from being on stage (i.e., as lecturers) and can circulate within the room. This allows new opportunities for teachers to learn about what students are thinking (Slotta, 2004), and new pedagogical opportunities for teachers to respond in “real time” to student ideas—which is one of the great strengths of such instructional approaches (Slotta & Linn, 2009). Thus, the patterns of interactions that occur within teachers’ classrooms during their lesson enactment are of relevance to this study. Video documentation (supported by field notes) was used to capture distinct types of actions: small group interactions (SGI) where the teacher interacted closely with small groups of students; large group interactions (LGI) where the teacher lectured the whole class; and isolated actions (Iso) where the teacher was working alone on grading or some other task during class time. Both SGI and LGI were subdivided into classroom management (M), pedagogical (Ped) interactions, and logistical (Log) support (e.g., setting up the apparatus). That is, a teacher could have whole class, or small group interactions that were coded as M, Ped, or Log, depending on the audio and video content of the interaction.

Video data was segmented according to the categories above, in order to provide a measure of the amounts of time spent in the various forms of interaction. While a rubric
could certainly be developed to allow a coding for any such interaction (e.g., a 1–3 score for how effective a small group interaction was, or how relevant to the lesson), such measures will not be employed in the present study. Rather, the video coding was limited to a supportive view of teachers’ patterns of interaction within their lesson enactment. How much time was spent at the front of the room? At what points in time did teachers engage students in small groups? How did patterns of interactions shift from the first implementation of a lesson to the second. Such questions can be addressed qualitatively through examining graphical representation of the percentage of class time spent on various forms of activity, adapting Stuessy’s (2005) method of video segmentation. Table 9 provides the coding scheme for video segmentation and annotation.

While all teacher enactments of all lessons were videotaped, the analysis of these data are beyond the scope of this dissertation, and will be reserved for subsequent research activity. For present purposes, videotapes of two teachers’ classroom enactments (across two iterations each) were coded in order to illuminate patterns of practice in the classroom that will complement other analyses described above.
Table 9
Video Enactment Documentation and Coding

<table>
<thead>
<tr>
<th>Segment Number</th>
<th>Segment Duration</th>
<th>Instruction (Codes)</th>
<th>Teacher Activity Patterns</th>
<th>What the Teacher Is Doing</th>
<th>Representations of actions</th>
<th>Student Actions What Students Are Doing</th>
<th>SGI</th>
<th>LGI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
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<td>3</td>
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<td>4</td>
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<td></td>
<td></td>
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<tr>
<td>5</td>
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<td></td>
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<td>6</td>
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<td>7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. Adapted from Stuessy, 2005*
3.9 Intercoder Reliability

Once the coding scheme was determined, randomly sorted statements from Lesson Plan and Enactment data collection (for Iteration 1 and Iteration 2) were selected. An expert rater was invited to participate in the rating of the coding schema. This rater had extensive experience in both activity theory and professional development research. The rater employed the same coding scheme as used by the primary researcher, and coded the same dimensions of elements and codes (i.e., subject, object, etc.), scoring each element with a 1, 2, or 3 based on the same rubric. Prior to the rating, the dimensions (codes and elements) were described and a brief training session occurred to help the rater understand the definitions of each of the elements (Appendix E). For the Lesson Planning coding schema, the rater achieved an 80% accuracy on elements ranked 1, and 80% accuracy on elements ranked 2, and an 87% accuracy on elements ranked 3. There were two discrepancies in test items for the Lesson Planning coding schema (Element items #6, #7), but the rater and researcher met to discuss these differences and, upon reaching satisfactory agreement on the items, achieved a consensus.

The Enactment coding was altogether more subjective, as it was based on a deep familiarity with the context of each teacher’s situation. Data that was extracted from this context could be interpretive and subject to contextual factors. For the Enactment coding schema, the rater achieved a 68% accuracy on elements ranked 1, a 63% accuracy on elements ranked 2, and 68% accuracy on elements ranked 3. The researcher and expert rater were able to discuss these inconsistencies within the items, and through careful negotiation, consensus was achieved.
3.10 Validating Findings

3.10.1 Clarification of Researcher Bias

It was recognized that the researcher-mentor should remain distant from any instruction of the class, particularly because she is also a science teacher, and thus could have influenced the enactment of the inquiry lessons. This potential contaminating factor was made explicit to the teacher participants, who agreed that they should not discuss the lesson in any way with the mentor if she was in their classroom (e.g., to collect videotapes) while they were enacting the lesson.

3.10.2 Member Checking (Teacher-Participants)

After teachers had completed their reflections before, during, and after the enactment, they were encouraged to read over their writing and confirm that they had addressed the reflection prompts. This allowed the participants to verify comments and ideas stated throughout the interviews and responses. To ensure the validity of reflections, teacher statements were matched up with observations made by the mentor during classroom enactments, as well as with final student artefacts.

3.11 Ethical Considerations

Ethics approval for this dissertation was obtained in September 2007 from the University of Toronto’s Office of the Vice President, Education Research Ethics Board (REB) and renewed each year (Protocol Reference # 20385). Appendix C provides samples of consent forms from one school board, and principals, the school science teachers, and the students and their parents/guardians.

The anonymity of the students, teachers, and schools were guaranteed throughout the entire process. All student questionnaires were completed with anonymous identification numbers so that nobody could trace the questionnaire back to any specific student. All students’
work within the wiki was also kept anonymous and confidential, with only the teacher able to see the student names. There was no foreseen conflict of interest, as the researcher was not involved with student assessments, and no prior relationship existed between the researcher or any of the participants, teachers, or schools. Students, teachers, principals, and one board of education were assured that all materials, interviews, and questionnaires would be used only for the purposes of research.

The interventions within this study—namely, reflection and collaboration—were explicitly presented to the participants, so that no deception was apparent (Creswell, 2007). Moreover, the task of designing and enacting a lesson was seen as professionally desirable to all teachers, and no remuneration, financial or otherwise, was made for their participation, with the exception of dinner being provided at the community meetings, and coffee for some of the interviews. The participants were offered a short summary of research results in between iterations to help clarify how they had informed improvements to the next iteration.
CHAPTER 4:
REFLECTION—IMPACT ON LESSON PLANNING AND ENACTMENT

This chapter presents analysis, findings, and results pertaining to the intervention of teacher reflection as a critical component in individual knowledge growth through lesson planning and enactment. The chapter evaluates teacher learning and the impact of reflection as seen through the lens of two Activity Systems: lesson planning and lesson enactment. Most results are presented in terms of coding schemes discussed in Chapter 3 (see Section 3.8). All results for teachers’ lesson planning are presented first, followed by results for lesson enactment. The last section of this chapter provides a discussion that connects the activities of lesson planning and enactment in terms of teachers’ knowledge development in the context of reflection within a community of peers.

4.1 Teacher Initial Understandings

Upon joining this study, all teachers were given pre-interviews and a set of initial reflection questions. These interviews were transcribed and coded, resulting in an initial assessment of teachers’ knowledge of project-based learning and use of technology in support of learning and instruction. Teachers were coded on these dimensions according to a rubric (Tables 7 and 8), resulting in scores that are presented later in this chapter. First, however, a short summary will be provided for each teacher that serves to reflect their beliefs and experiences as captured by these initial measures. While somewhat qualitative and interpretive in nature, these paragraphs seek to provide a richer description than the codes, tables, and charts that will follow.

4.1.1 Summary Descriptions of Teachers

Teachers were asked a series of questions prior to the study in order to understand their background experiences and perspectives about project-based activities and technology-enhanced learning. Analysis from interviews, prior classroom observations, and wiki responses
resulted in the following initial descriptions of teachers’ understandings about student knowledge, project-based learning, use of technology, and practices of reflection and peer-exchange.

Bill was a veteran teacher with 25 years’ experience who joined the project in Design Phase I (i.e., when the peer community was rather limited), and wanted to build a project-based lesson for his high school chemistry class. He was quite reflective orally but wrote very little down (e.g., reflections, changes in lessons), although he acknowledged the importance of reflection. In the initial interview, he states, “Absolutely…see the benefits in the reflective process from this study.” He also acknowledges that the use of technology and project-based approaches had not been a focus in his teaching. He considered himself a “new” adopter of technology. His comments about his “wider community” included the parents and administration, but did not mention his peers. He had been a department head and recognized that colleagues in the department did not have the same philosophy of sharing or exchanging resources due to time constraints. Bill had a good idea about the type of concept that should be taught in a “project-based” fashion. He wanted to use the topic of “acid and base chemicals” for this activity because he thought that the science concepts involved would make a project authentic and relevant. He felt that it was beneficial to learn about these chemicals at home, as students would acquire knowledge about science in real-life situations. Additionally, he conceived of the notion that students could actually do parts of the project at home (lending further authenticity) because many of the chemicals could not be used in the schools anymore (such as Javex). He felt that students could learn about natural indicators, about safety and storage of chemicals at home, and about how to conduct an experiment.

Placido was another veteran teacher, with 30 years’ experience, who joined the project in Design Cycle II (i.e., when the peer community was already established). He was the head of his
school science department and wanted to develop a project-based lesson for his high school Grade 7 science class. He was very traditional in approach within his class (by his own admission) and used technology in limited ways. Placido felt that reflection was similar to “thinking deeply” and because of his tenure and position within his school, he did not believe that his wider community had a great impact on his practice. Placido’s main emphasis in developing concepts for his project-based lesson was that all the students would cover similar material, and he chose a topic of geographical information to promote understanding about volcanoes and earthquakes. He emphasized his ideas through didactic notes and felt that pen/paper tests were important: “I find that students’ process is important; acquiring and getting good notes to study from them; extract information from text and write a good test from this.” He believed that project-based learning was more appropriate for the younger grades rather than the older because the latter grades required more preparation for university, and marks are difficult to assess in project group work. Placido utilized another teacher’s (Alex) project-based lesson plan, and did not really participate in the technology design of the project because of his lack of comfort with technology, as well as personal health circumstances.

Olga was a relatively new teacher, with only three years’ experience, who joined the project in Design Cycle II and wanted to develop a project-based lesson for her high-school Grade 12 chemistry class. Olga liked to emphasize real-life concepts within her class. She recognized that students’ prior understandings often do not incorporate the “overall picture” of the concept, and wanted to make chemistry “real” in her instruction. She enthusiastically stated that project-based activities were great for students because they were open-ended, and would enable students to be collaborative and motivated. She commented about the project, “I see it helpful in two ways. For one, it’s the extension of the knowledge, because they’re just going much more in depth into whatever subjects that they’ve chosen to find interesting. And
[secondly] the fact that we’ve actually posted the posters. I mean every time before a class I always see them reading each other’s myths and kind of discussing it.” She liked using technology for enhancing learning but wasn’t really sure how to succeed with technology-enhanced methods. She realized that her reflective practice was limited, but she liked the idea of reflecting within a community of peers. She felt that community benefits the individual teacher by forcing organization and by making lesson changes more visible. For example, she commented that in August, the community meetings helped focus the type of project and the science concepts she chose. Through this discussion, every teacher contributed to the final design, making the overall project more substantial in nature. She valued community as she saw it important to her own development. She began this study with an already established peer-exchange community and was an active participant. Despite her limited teaching experience, Olga was a very reflective educator with diverse interests including social justice issues in science education and technology integration. The project-based activity that she worked on was modeled after a television series called *MythBusters* and involved chemistry students finding chemistry myths, presenting them, then collaborating to defend or refute a myth other than the one they had presented. It involved high level critical thinking for the students with multiple tasks that extended the project.

Daryl was a new teacher, with only three years’ experience, who joined the project in Design Cycle I and wanted to develop a project-based lesson for his high school applied level Grade 9 science course. He liked the idea of project-based activities because of the multimedia content (i.e., pictures and movies) that they might contain, which he felt might help students to better understand topics. Explaining his commitment to such a visual approach, Daryl said, “Students would be able to watch and see the actual movements (simulations) of reactors and other energy types.” His technology experience was limited, and he expressed quite generic ideas
about reflective processes and assessments. His experience with community was limited in his own school and those within the study. Daryl did both of his lesson iterations (planning, enacting, and revision) within the first design cycle, and although he was invited to community meetings when they began, he stated that he had only committed to repeating the project-based technology-enhanced lesson twice, and remained outside the peer community. He chose two different science concepts for his project-based lesson iterations: reproduction and electricity. He was brief in his reasoning, saying that this approach would help students build on their “foundational knowledge.” He commented that the key prior knowledge required for students was knowledge about the technology (e.g., PowerPoint and Internet use). He chose the two lesson concepts because he felt they were relevant to everyday life, and because students would be able to talk about how energy was used in their neighbourhood.

Maddie was a relatively new teacher, with five years’ experience, who joined the project in Design Phase II and wanted to develop a project-based lesson for her high school physics class. Although she was very new in the use of technology, she felt that with the support of a co-design process with lesson planning and enactment she would be able to handle the technology, including the video aspects of the project. She really hadn’t done much project-based work or incorporated much technology into her own lessons. She comments, “Sometimes in the biology, only 5 kids did a lot of the work (in projects)”. She was reflective but more informally. For example she liked to go back after the lesson was implemented to see what happened, what worked, and what hadn’t worked, but not regularly. Maddie considered conversation with peers about her class and lesson design to be beneficial. Her school required departmental meetings to encourage professional development. She was very excited to join the research study and was a very active participant within the peer community. Ultimately, this would lead to real advantages, as she was able to draw on another teacher-participant’s student-created video
project as an inspiration and guide for her own. She liked the idea of making the problems explicit and having the students demonstrate the laws of physics, agreeing that project-based lessons needed to be open-ended and grounded in relevant student experiences. She noted that the students’ interaction with the wiki site would provide her with new opportunities to manage student interactions and feedback.

Alex was also a fairly new teacher, with six years’ experience, who joined the project in Design Phase II and wanted to develop a project-based lesson for his middle school (Grade 7) earth science class. Alex had limited experience with technology in his past student activities. He was drawn to participate in this project because he saw it as being fun and motivating. He noted that his lesson designs would be completed during the course of his regular instructional time, and was cautious of “too much homework” because of parent concerns. Alex was interested in working with other teachers and was comfortable with the notion of project-based curriculum and assessment. Because he joined the study in Design Phase II, he was able to join an already established community of peers, which, as in the case of Maddie, offered an active, established social group to which Alex contributed also. His idea for a project-based lesson was to engage students around concepts of the Earth’s crust, encouraging them to make personal connections (e.g., to their rock collections at home, or local geological features). His lesson was organized around the idea that landforms in North America and Europe are constantly changing, and he included activities where students discussed their ideas in online forums. He was concerned that students might not have a lot of prior knowledge about the concepts. The final digital project in Alex’s lesson involved group presentations with interactive digital media.

Charlie was the most enduring participant in the study. He joined the study in the first design phase, and remained throughout all phases over the three years. He was interested in developing project-based lessons for his high school physics course. In his prior teaching, he
often used hands-on demonstrations to clarify concepts and illustrate physics concepts. He used lab reports and design-your-own experiments as examples of project-based learning. Initially, his understanding of project-based activities was limited and his use of technology was quite teacher-centred (i.e., to be used as a lecture aid). He had frequently used his tablet computer, connected to a projector, to present physics concepts to his students, and would sometimes adapt his lesson based on students’ responses, but he never wrote down any plans, nor reflected formally on what was working and why. His understanding and experience with peer community was limited initially, but grew as the study introduced new teachers and the community design improved. He was the most engaged of all teachers in the study, and completed four iterations of designing, enacting, and revising his lesson. Charlie was also a community leader and participated in all the community meetings. He was aware that it is important for teachers to address students’ prior knowledge, and that students do have misconceptions about science topics. He liked to read and learn about his students’ ideas through the project, “They [student] fell down, they got all muddy…then I’m right there with them. I’m experiencing it, and so regardless of whether they learned anything at all, just sharing that experience in a coherent way was important.” For his project-based lesson, he wanted to develop a video project for which students create their own video to represent physics topics like sound, as he felt it could be more descriptive and easier for the students to communicate their ideas through this open-ended project than a traditional test.

Merle was a veteran teacher, with 25 years’ experience, currently working in a unique science centre school. She was very keen to develop a project-based lesson, connected to real-world concepts that would be meaningful for her students. She joined the project in its second design phase, and was an enthusiastic participant in all community activities and meetings. She described how students come to school with different backgrounds with a wide range of prior
knowledge, which presents challenges to their learning but could hold great opportunity as well. Merle commented that project-based learning “forces students to think about problems and work through solutions. And they are working with other people, so they are gaining knowledge from other people’s ideas and experiences.” She favours project-based work because it is collaborative and “hands on, allowing students to learn by manipulating things and using different areas of their brain to be more creative.” At the outset, she was quite tentative with respect to technology, although she had used probeware and knew about wiki technology. Merle was very thoughtful and reflective, and recognized that engaging in the written reflections within this study could be important, “otherwise you will forget your realizations.” She enjoyed working with her own peers and had created a collaborative atmosphere within her previous school, where she served as the science department chair. For her project-based lesson, Merle wanted students to work on a project that would take them into the science centre’s public facility; they would work collaboratively on a podcast that described several of the exhibits pertaining to junior level science. The activity required them to use their prior knowledge from the Grade 11 physics course. This would expose the gaps that these students had in their own understanding of science concepts.

Frank was a relatively new teacher with six years’ experience who wanted to develop a project-based lesson for his middle school (Grade 7) biology course. He joined the project in the first design phase and was enthusiastic, but was unable to progress to a second iteration because his contract expired and he did not get another one in that year’s competitive teaching marketplace. This was an unfortunate circumstance and the kind of event that studies such as this one must allow for. Frank was optimistic about project-based learning, stating that it helps “students learn from each other and from other sources rather than the teacher and the textbook.” He spoke about the value of reflection, in that it allowed him to identify the parts of the lesson
related to the “big ideas” and to think of different ways to achieve the same goals (i.e., to consider the costs and benefits of different approaches). He felt the pressure of the school schedule and commented on the lack of time to find good resources (including technology) and assessments that matched with project-based learning. He enjoyed the community experiences, as he liked sharing ideas and cooperating with others within his department. For his project-based lesson, he chose to engage students in a Web-based Inquiry Science Environment (WISE) project concerned with ecosystem concepts such as population, community, and biotic and abiotic factors. WISE projects are designed to help the students to think critically about issues such as endangered species, food webs, and ecological systems (Slotta & Linn, 2009). While WISE is viewed as a project-based technology-enhanced learning environment, Frank chose to add an additional final artefact of asking students to create a fictitious news report (on video or in audio). He hoped that his students would make connections to their learning from previous grades concerning food webs, and he believed that engaging students’ existing ideas was important to help them develop their understandings of science topics.

Table 10 summarizes the teacher-participants in this study with respect to project-based teaching and technology experience, with teachers’ scores based on the rubric presented in Appendix D. 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 10

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 1</td>
<td></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 these scores 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.
4.2 Teacher Learning Through Lesson Planning

This study relies on teachers’ reflections, field notes, and follow-up interviews to develop insights about how teacher knowledge develops through engagement in the activity of lesson planning. A wiki-based lesson planning template (shown in Chapter 3) was designed to help guide teacher-participants but also to make explicit the thought processes that teachers undergo when designing a lesson. This template was meant as a suggested format, and most teachers made some deviations from the specific headers provided. Figures 9 and 10 show two examples of lesson plans developed by Charlie and Olga, respectively.
Figure 9. Sample lesson plan: Charlie’s video lesson plan

**SCH4UE-01**

*Chem’myth’try Busters STAGE I*

This is the space where you can generate your own Chem’myth. This is myth about some chemistry concept or idea that you have heard or read about but you are not so sure if it is fact or myth. Your mission is to write up this myth.

A template is created for the following assignment. The template will look like the following page. Do not write on this cover page. Click on the link below (in red) - once you have decided what format for myth you would like to present in (i.e., collage, article, or video). Then, on the new page, go to ‘edit page template’. Click on “chem’myth’try busters stage 1” and click on ‘next’. You can now begin filling in the page. This will be your new page. You can now change the name of the page to reflect your myth.

Defining your myth. Due Date: Sept 17, 18 for evaluation click on insert link to attachment

Summary of Myth (max 150 words)

Figure 10. Sample lesson plan: Olga’s Chem’Myth’try Busters

The definition of a project-based lesson was explained at the outset of this study, but several of the teachers considered the characteristics of project-based learning to be “educational jargon.” These teachers felt that they knew what project-based learning meant and were sympathetic to its role in student learning, but were skeptical about formalizing its process and implementation. For example, consider the following quote from Charlie:
... documenting them in terms of labelling this, and labelling that, and compartmentalizing them as being separate things, when I’m asked for whatever, teachers’ performance appraisals or things like this to kind of just…you know, give me the phrases that we like to hear that you are doing. It kind of bugs people, speaking for myself, a bit. Or, I guess I am saying that I don’t particularly enjoy the effort put into that kind of documentation, shall we say. (INT 210108)

Many of the teachers felt that they had previously used project-based activities in their class, although not following all the criteria outlined within this study. In addition, teachers were intrigued with the use of technology. They recognized an opportunity to learn and implement technology into their lesson plan in meaningful ways.

Throughout this study teachers generally made their own decisions and commitments about what constituted “project-based learning,” and did not make strong efforts to fit their lesson designs to the criteria provided. Still, the criteria provided an important resource for discussion, and a metric for evaluating lessons. Using the lesson template, wiki reflection, and interviews, teachers’ understanding of project-based strategies for particular science concepts become evident. Technology embedded within their lessons helped teachers follow students’ progress and collaborations within the curriculum and provided a means of formative feedback. All teachers felt that their project-based lesson design was a success in some way.

Clearly, the activity of lesson planning is complex and heterogeneous in terms of its constituent elements. Teachers may have an idea about a lesson in a meeting with a mentor, then read something later that day or have a discussion with a colleague that influences their ideas. They may take some notes, think about the plan while riding the bus home, edit their wiki page, then talk to the mentor again. Throughout this process, teachers must consider a variety of factors, including the curriculum expectations, the school calendar, technology resources, student ideas and capabilities, and (in this case) the criteria of project-based learning and one or more technologies. This process may go on for weeks, even, before the final lesson plan is completed. The activity-based coding scheme was developed, as reported in Chapter 3, to represent elements
of a lesson planning based on a variety of evidence and data. Teacher knowledge (Subject),
quality of lesson plan (Object), reflection (Rules and Tools), and community were all addressed
by a variety of elements in the rubric, scored, and then interpreted to gain insights into teacher
understandings about the lesson plan. This coding scheme thus provides a coherent
representation of such a varied and diffuse practice.

4.2.1 Analysis of Teacher Knowledge (Subject)

The first three elements of the coding scheme for lesson planning comprise the
“Subject”—in the sense that together they represent the score of the subject of this activity
system, namely, the teacher and his or her knowledge of lesson planning. 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).

While the constructs of PCK and TPCK have been construed in the research literature as
evasive of direct measure, and therefore only accessible through inference and interpretation,
they are nonetheless seen as valid forms of teacher knowledge that can only be measured within
the context of authentic teaching practices. The coding scheme draws upon a range of data
sources, including teachers’ lesson templates, wiki reflections, interviews, and field notes. Each
element (row) within the Tool was coded with a value of 1–3, as described previously in Chapter
3 (Section 3.7), according to a rubric (see Appendix D).
Figure 11. Coding scheme for lesson planning: Subject elements

The following excerpts from teachers' reflections about their lesson plans provide evidence for one element, “Selection or choice of content.” This element was important to show teachers' thoughts on the connections between content and pedagogical strategies. Such statements were rated on a 1-3 scale, according to the rubric (see Appendix D) as previously described. For a score of 3, the teacher-participant had to respond with specific words about the science concept, words about how the student group work would occur, and words about collaboration. Statements below provide examples from each level of the rubric.

**Rubric: Score of 1.** Response has no relevance for content-concept and project-based learning.

*Excerpt: ... following along with the physics unit of energy resources (Daryl wiki 130508)*
Rubric: Score of 2. Response has limited reference to content-concept and project-based learning.

Excerpt: I was able to look at expectations and determine my goals. I wanted to accommodate some of the curriculum expectations. You now cannot bring things into the school (e.g., household products—like bleach, Javex) cannot be seen at school. Thus, this project-based work done at home...effective way (no class time required). (Bill wiki 210509).

Rubric: Score of 3. Response has strong reference to content-concept and project-based learning.

Excerpt: Such a lesson would allow the students to interact with their peers not only through oral communication but by the use of technology (wiki) which would hopefully enhance their communication skills. With these skills and more "hands on" projects such as making videos of Newton’s Laws from start to finish would hopefully allow them not only to develop technological skills but also to have a true, better understanding of the concepts they learn in class. I would set it up before hand by telling them my expectations of the project, once the project was complete, I would have an open discussion with the students about their experience with it. The completed project could always be referred to in the future to help them recall the concepts worked on at the time. (Maddie wiki 121208).

The “Subject” score, which is taken to reflect some measure of PCK, improved from Iteration 1 to Iteration 2 for five of the six participants (see Figure 12). Thus, teachers demonstrated improved pedagogical content knowledge in their second planning cycle, as measured by the average score of the three elements highlighted in Figure 9. This presumably is partly the result of their engagement in the first cycle of reflective planning and enactment. Notably, the teachers who began with the highest measure of PCK showed the least gains, reflecting a “ceiling effect,” where the teachers simply had little room for improvement on the measures employed (Creswell, 2009). Note, data from only six teachers are presented in Figure
12, as only six teachers managed to complete two cycles of planning and enactment. Bill was the lone exception to this finding, scoring lower on the Subject measure in his second iteration than he did in his first.

![Bar chart showing Teacher Knowledge Iteration 1 and Iteration 2](chart.png)

*Figure 12. Subject measure: Iteration 1 and Iteration 2, reflecting growth in PCK*

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. These teachers gained some pedagogical knowledge related to project-based technology-enhanced lessons from their participation in the peer community. The community interactions and effects will be discussed in Chapter 6.

Isolating the element of technology pedagogical content knowledge (TPCK) from the other elements in the rubric (i.e., restricting the analysis to the third element only) indicates a similar increase in score from Iteration 1 to Iteration 2 (see Figure 13). 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.

![Bar chart showing improvements in TPCK (or TPACK): Iteration 1 to Iteration 2](image)

*Figure 13. Improvements in TPCK (or TPACK): Iteration 1 to Iteration 2*

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 rubric. 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.

4.2.2 Analysis of the Quality of Lesson Plans (Object)

The “Object” of the lesson planning activity was identified as the lesson plans themselves, which were evaluated according to the project-based learning criteria (including the use of technology). The teachers-participants needed to create lessons that connected to student ideas and inquiry-based projects, and built on the student understanding. Figure 14 shows the elements from the coding scheme that were used to obtain this measure. Field notes, wiki responses, interviews, and the wiki-based lesson plan itself provided evidence for the coding of the eight constituent elements.

<table>
<thead>
<tr>
<th>Lesson Planning Rubric</th>
<th>Participant’s Name:</th>
<th>Cycle:</th>
<th>Subject Discipline:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Project:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Category Label</strong></td>
<td><strong>Quality Range</strong></td>
<td></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>Subject</td>
<td>1-3</td>
<td></td>
<td>What reasoning does teacher give for using this particular content-concept for this project work (PBL)?</td>
</tr>
<tr>
<td>Subject bound to the strategy</td>
<td></td>
<td></td>
<td>What reasoning or demonstration within lesson plan is given for student learning of science is directly (or indirectly) related to the pedagogy (PBL)?</td>
</tr>
<tr>
<td>PCK: understanding of technology and use of it to improve the project design</td>
<td></td>
<td></td>
<td>What reasoning or demonstration within the lesson plan - does teacher give about the use of technology either to help the science content or help the project process?</td>
</tr>
<tr>
<td><strong>Object (including project-based index * all within lesson plans)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connecting to student ideas</td>
<td></td>
<td></td>
<td>How does the lesson plan connect to student ideas (addressing of prior knowledge)?</td>
</tr>
<tr>
<td>Inquiry-based project; exposes students to relevant ideas</td>
<td></td>
<td></td>
<td>How does the lesson make the assignment more relevant to the everyday life (i.e., practical and authentic)?</td>
</tr>
<tr>
<td>Building on student understanding</td>
<td></td>
<td></td>
<td>How does the lesson plan allow students to construct new knowledge (ideas) from their own knowledge - i.e., use of mind maps, concept maps, brainstorming, allowing for the free expression of their own thoughts connecting to the project?</td>
</tr>
<tr>
<td>Active student involvement in the process</td>
<td></td>
<td></td>
<td>How does the lesson plan motivate student involvement in the process of the project-based learning (teacher designs student choice for feedback process)?</td>
</tr>
<tr>
<td>Teacher facilitation of project</td>
<td></td>
<td></td>
<td>How does the lesson plan incorporate specific scripts and roles for teachers in the project? (Outline the area in which teacher upper is required, teacher plays a role in the process components of the lesson)</td>
</tr>
<tr>
<td>Assessment of the PBL-project</td>
<td></td>
<td></td>
<td>How does the lesson plan include assessment components of the project (and check point for addressing student learning, possible connections to revision of lesson, or adjustment to lesson)?</td>
</tr>
<tr>
<td>Science concept taught</td>
<td></td>
<td></td>
<td>How does the lesson plan address the science concept taught through PBL (description within lesson plan) - is it supplementary or is it a deeper science content?</td>
</tr>
<tr>
<td>Type of Technology (video, wiki, ppt, etc.)</td>
<td></td>
<td></td>
<td>What type of technology choices and resources were included in the lesson plan? How did teachers use the tools for their lesson?</td>
</tr>
<tr>
<td><strong>Rule/Tool</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Able to articulate teacher-learning prior to enactment (reflection pre-enactment) metacognition</td>
<td></td>
<td></td>
<td>How does the teacher use evidence of the lesson construction as a way to see student learning (challenges), PCK, and problems with logistics? Did teacher reflect on student’s needs and make any changes?</td>
</tr>
<tr>
<td>Able to articulate student learning prior to enactment (2nd X reflection)</td>
<td></td>
<td></td>
<td>How does teacher recognize student learning before enactment and the importance of the enactment?</td>
</tr>
<tr>
<td>Able to articulate teacher-learning prior to enactment (2nd X reflection pre-enactment) metacognition</td>
<td></td>
<td></td>
<td>How did teacher use knowledge of the lesson construction (after enactment) as a way to see student learning (challenges), PCK, and problems with logistics? What kind of evidence happened that prompted changes in the lesson plan?</td>
</tr>
<tr>
<td>Deo of Labour &amp; Community</td>
<td></td>
<td></td>
<td>How productive was the mentor in the lesson design? How heavy was the mentor’s role in the process? Did the teacher use mentor’s ideas and make it their own?</td>
</tr>
<tr>
<td>Influence of Community</td>
<td></td>
<td></td>
<td>How did the community (people) influence their lesson plan?</td>
</tr>
</tbody>
</table>

**Figure 14.** Screen capture of lesson design rubric coding schema (Object elements)

The following excerpts from teachers’ lesson plans illustrate specific evidence for one of the elements, “Building on student understanding.” This element was critical as it showed
teacher understanding of not only student learning but also how teachers would use the student ideas in further lesson instruction. Such statements were rated on a 1–3 scale, according to the rubric (see Appendix D) as previously described. A score of 1, teachers would not a very generic statement about student learning and would not support their answer with an example from the project work. Statements below provide examples from each level of the rubric.

**Rubric: Score of 1.** Response has limited opportunities for building on student ideas (limited constructivism)

*Excerpt:* Many of the science concepts were taught in the lesson and is done through the page—online environment. I present the information as many ways as possible—and the students are able to work on this—because we are dealing with a variety of learning style. (Bill wiki 210509)

**Rubric: Score of 2.** Response somewhat links and builds on student understanding (evidence of constructivism, although inconsistent)

*Excerpt:* Harry Potter—exemplified ideas from the first cycle. I wanted the kids to make something that was funny. Plus, in physics, teachers often feel(s) that the students don’t think they like concept-themes of physics. The students were on a Harry Potter kick from the beginning of the year. Harry Potter storyline and references were recreated and written cleverly. Characterization kept true to (not boring to watch). Before you know it they are doing physics…Pop culture, their own interests and physics squished in there…Students commented… "Not sure what you meant by this, use visual, encouraging. Don’t copy Mr. Charlie’s rap—use your own.”…I liked student comments and I facilitate these comments. (Charlie wiki 131208)

**Rubric: Score of 3.** Response strongly builds on student ideas

*Excerpt:* Misconceptions on the lesson or science concepts? I will answer with regard to the lesson…they might be inclined to think they must prove something is WRONG with their own evidence, which can be very challenging. They might be overwhelmed if they don’t thoroughly understand what is being asked… I might be addressing a later question … but I think after
they’ve done the chemistry (within the project)… some of the questions that they come up in class, I’ve often been able to relate it in the chemistry lesson and say, “yes, that’s why somebody (student) addressed those questions in the myth.” So we always have that relatable moment because of the myths…(Olga wiki 261208)

The total of all element values in the “Object” category of the lesson plan coding scheme is graphed in Figure 15, for the six teachers who completed two iterations of lesson planning and enactment. Again, this figure shows the improvement in teachers’ lesson plan from Iteration 1 to Iteration 2, which suggests that the first iteration of reflective activities had a beneficial impact in the quality of lesson plans in the second iteration.

![Figure 15. Lesson planning score: Iteration 1 and Iteration 2](image)

It would be expected that when teachers revise lessons that they had designed and enacted, they would improve those lesson plans. This proved true for the five participants, with the exception of Bill, whose lesson plan included less student collaboration and interactions in Iteration 2 than it did in Iteration 1. Although he added some scaffolding within the overall
structure and more detailed instructions, Bill used the technology as a platform to guide his lectures, with no scaffolding questions for students’ experimentation, and little inquiry involved within the final student project. Thus, Bill’s overall lesson plan score actually decreased in the second iteration, according to the coding rubric.

4.2.3 Analysis of Reflections (Tools and Rules)

Scaffolded teacher reflections were integral to the design of this study. In the Activity System coding, reflections were seen as both a “tool”—a specific wiki scaffold with prompts, used at strategic moments in the activity to allow teachers to develop a sense of perspective about their lesson—and as a “rule,” since they were provided to teachers as part of the required elements of the study. Scaffolded reflections about the lesson plan prior to enactment were scored according to depth and breadth, were focused on topics of student learning, on the ability to recognize and respond to student challenges, and on identifying points for subsequent lesson plan revisions. Once again, the coding scheme for lesson planning and corresponding rubric were used (see Figure 16 and Appendix D), which provided specific elements to examine in measuring engagement in reflection.
Figure 16. Screen capture of lesson design rubric coding schema (Rule elements)

Below are excerpts that demonstrate the reflections from Iteration I and Iteration 2 for the element “Able to articulate teacher learning prior to revision of lesson plan.” The statements were scored according to the rubric on a 1–3 scale, as previously described. A score of 2 versus 3 is distinguished by the teacher-participant being very explicit how they were going to revise the lesson using project-based strategies. In below excerpts, a score of 2 comments about lesson construction in general way, but a score of 3 comments about lesson construction as a process and offers steps to guide teacher.

**Rubric: Score of 1.** Response has limited understanding of how lesson construction could provide ways to view student learning, technology implementation, and logistics.

**Excerpt: Making classroom space—find I have to leave for various reasons; My favourite thing is still lesson when I (teacher is) am engaging. I find that during the class, I feel not as productive. I am walking around (as students working on project)...I feel like I am not helping.**

(Charlie wiki 140208)
Rubric: Score of 2. Response somewhat links to how lesson construction could provide ways to view student learning, technology implementation, and logistics.

Excerpt: Facilitate (the students)! It will be a huge job to organize and stay on top of where they are flowing, because if I let them go on the wrong path they will spend much time going the wrong way which will have the opposite outcome—to unmotivate them. (Olga wiki 131008)

Rubric: Score of 3. Response strongly illustrates how lesson construction could provide ways to view student learning, technology implementation, and logistics.

Excerpt: As I walk around the classroom I will be listening to and engaging in conversations. I'm trying to determine the type of background the students have in the topic they have chosen, make sure they are on task, help to clarify where needed and generally act as a resource to point the students in the right direction. (Merle wiki 130309)

Scaffolded reflection was seen to be very important to teachers’ success in lesson planning, as well as in their improvement in lesson planning across iterations. Teachers with higher overall reflection scores achieved better lesson planning scores. Figure 17 shows that, in the first iteration, the correlation of these two measures was significant, with $F(1,7) = 17.881$, and $p < .001$ ($R = .843$, and adjusted R squared value .711). Of course, it is also important to recognize that the scoring method employed was biased towards more reflective teachers, as the rubric essentially employed teacher reflections as the data source for many of the elements within the Tool. Thus, it would be expected that more reflective teachers scored higher on the lesson planning measures as well (e.g., Maddie or Merle). Lesson plans within the second iteration had similar positive correlation, but lacked statistical significance.
One set of elements within the coding scheme for lesson planning that was not dependent on teacher reflections was that concerned with the lesson plans themselves (i.e., the “Objects” of the activity system). Figures 18 and 19 show a strong correlation between the teachers’ lesson plan (Object) and their average reflection score for Iteration 1 and Iteration 2, respectively. Figure 18 shows that in Iteration 1, the lesson plan score (Object) correlates significantly with the reflection average, with $F(1,7) = 5.668$, and $p < .05$ ($R = .669$). Figure 19 shows the same correlations of lesson plans with reflection for Iteration 2, with $F(1,4) = 24.872$, $p < .005$ ($R = .947$).
These correlations provide some evidence of a link between the quality of teachers’ reflections and the quality of their designed lessons. Teachers who used the tools and followed the rules of reflection consistently showed improvements in their overall lesson planning score from the first to the second iteration. Presumably, these improvements were partly due to teachers’ reflections about the strengths and liabilities of the lesson in the first enactment. Thus,
scaffolded reflection throughout the course of these two planning and enactment cycles appears to play a productive role in helping teachers improve upon their lesson designs and improve as lesson planners.

The results of the activity-based codings suggest that engagement in reflective cycles of planning, enactment, and revision encourages development of PCK and leads to improved lesson plans. Teachers who were stronger in their scaffolded reflections had better scores on both lesson planning (i.e., overall) and lesson plans (i.e., just the object component). These strong positive correlations reinforce the notion that those who reflect more deeply during lesson planning make greater gains in PCK and hence in their capability for subsequent lesson planning activities. The next section analyzes lesson enactment as an activity system, examining reflection during enactment as an important component of successful enactment, growth of PCK, and improved enactments across the iterations.

**4.3 Analysis of Lesson Enactment**

The review of constructivist learning and teacher knowledge presented in Chapter 2 argues that teachers gain PCK through engagement in professional practices. This study sought to investigate the impact of reflection and peer community on a coherent cycle of practice involving lesson planning, followed by enactment, then revision of the lesson based on reflections about student achievement. Thus, it is important to create a similar mapping to the (complex and heterogeneous) activity system of lesson enactment, then conduct a set of comparisons that are parallel to the ones conducted in the previous section. As the teachers enacted their project-based technology-enhanced lesson, I hypothesized that PCK was developed, and that their engagement in active reflections promoted the process of knowledge development.
4.3.1 Analysis of Teacher Knowledge (Subject)

As in the case of lesson planning, the eight-step method was followed to identify the six nodes of the lesson enactment activity system (see Section 3.9). A coding scheme was then established, connecting various forms of evidence to the various nodes, as shown in Figure 20. The Subject elements were drawn from literature of PCK and TPCK. The first five elements of the coding scheme constitute the “Subject” node of this activity system: the teacher and his or her knowledge of lesson enactment. These five elements are as follows:

1. Setting the context of the lesson
2. Ownership of the lesson
3. Technology pedagogical content knowledge
4. Addressing the fluidity of the lesson
5. Small group interaction

As in the lesson planning coding scheme, each of these five Subject elements were scored from 1 (lowest) to 3 (highest), according to a rubric, as shown in Appendix D. The total of these five element scores (or their average) for the “Subject” node provides a measure of pedagogical content knowledge (PCK), including the subconstruct of technology pedagogical knowledge (TPCK: see element #3).
Similar to the analysis conducted for the lesson planning activity system, the enactment coding drew upon a range of data sources, including teachers’ wiki reflections (collected during and just after their enactment), interviews, field notes, and videotape. For instance, coding of the first element, “Setting the context of the lesson,” looks at the way a teacher introduces the concept and overview of the project-based lesson to his or her class. The following are samples of scored excerpts for this first element in the Subject codes.

**Rubric: Score of 1.** Response has limited instruction and explanation of context for lesson.

*Excerpt: Yes, students worked collaboratively well together, while furthering their education on asexual reproduction. Sexual reproduction was not included as previously stated in the objectives. The comparison was based on the 5 types of asexual reproduction. Originally we planned to have a PowerPoint lecture, giving information to the students on how to set up...*
PowerPoint slides. But after talking to the students we realized that they were quite comfortable with the program (Daryl wiki 111107).

**Rubric: Score of 2.** Response has some explicit instruction and explanation about context for the lesson

Excerpt: Students went through WISE projects (Wolves Management)...reading the site, checking the links...listening to wolf howling (half of students were engaged—may be due to their own work pace); watching videos (half students); some could not locate it video initially; other students I had to helped them find the video from the link; instructions within WISE helped students navigate through site;...showing students about how food webs influences wolf population. (Frank wiki 100508)

**Rubric: Score of 3.** Response has explicit instruction and explanation about context for the lesson.

Excerpt: Students worked in pairs to complete the activity. They were refining their scripts so there was a lot of discussion going on (about science concept and exhibit). The students were also doing research using websites and (in) their textbooks to make sure that what they were saying in the podcast was accurate information. There was also discussion between groups asking for help to understand a concept or advice on how to explain it. (Merle wiki 121208)

Figure 21 illustrates the “Subject” scores for six teachers who completed Iteration 1 and Iteration 2. These scores are taken to reflect some measure of PCK, and again noticeably improves as a result of a reflective enactment process. Interestingly, the teacher who had the highest Subject score in the first enactment (Merle) had a relatively modest gain in this knowledge, from Iteration 1 to Iteration 2, again suggesting a “ceiling” effect. Bill was the only participant whose enactment score was lower for his second iteration than for his first.
Figure 21. Average Subject score for six teachers’ enactments (two iterations)

4.3.2 Analysis of the Quality of Enactment (Object)

Similar to the analysis of lesson planning, the “Object” node of enactment was evaluated according to criteria of project-based learning and technology integration (e.g., Did teachers make connections to student ideas during class? Did they expose relevant student ideas? Did they build on students’ understanding and enable collaborations? (See Figure 22.) In addition, teachers were assessed in terms of their achievement of lesson plan objectives, implementation of assessments, teaching of science concepts, selection of appropriate technologies, and ability to make changes to their lessons during class time. The Object elements of enactment closely followed the Object elements of the lesson plan. Field notes, wiki reflections, interviews, and student-created artefacts provided evidence for the scoring of these elements, from 1 (lowest) to 3 (highest), according to a rubric, as shown in Appendix D.
Figure 22. Screen capture of the Enactment coding scheme (Object elements)

The following are samples of scored excerpts for one of the elements, “Enables planned student activities (collaborations)”, in the Object node. While distinguishing between a score of 2 and a score of 3 could be problematic, the vocabulary and the details that the teacher choose to describe during the enactment made the scoring more explicit. In the following excerpt, a score of 3 indicated a detailed descriptive understanding of how the group interactions were occurring and what the teacher interactions were within the small groups.

Rubric: Score of 1. Response didn’t address small group interactions.

Excerpt: How did you assign groups for the collaborative work? This part individual—therefore N/A. Next stage, it will be by picking out of a hat. (Olga wiki 220808)

Rubric: Score of 2. Response addresses small group interactions in some way.

Excerpt: (Re: collaborative groups...) Based on their “table” groups. They share similar interests. Having the film festival day as an absolute deadline. One-on-one chatting with them,
asking them questions about the project. Videos were done in the both cases (iterations) within table groups. The log books helped me (understand collaborations)—I enjoyed reading it. I assumed that knowing that they had to fill in something out, made the student feel that they should be working on something (every) day. (Charlie wiki 290508)

**Rubric: Score of 3 Rubric.** Response strongly addresses small group interactions.

Excerpt: Yes, I think there is a difference between how students learn from simply listening to a teacher talk or show demos to actually researching the topic themselves and seeing other versatile examples of the topic or other ways of the topic being presented. Also students had to be creative in this project which implies that they should know and understand the topic well in order to present it in a unique way. For example, I showed some demos in class of a physics concept, the students then saw similar demos on line, which gave them ideas about how they can present the same topic, but in their own unique way.

The same problems existed that normally exist in a nontechnological group work effort—some students end up doing more work than others (in a group). However, there was more collaboration since students were aware that their progress was being observed and assessed online. Making them aware that their progress was being monitored online and their assessment was based on how much work they contributed to their wiki site as well as the project itself. Also, giving them strict deadlines for various stages of the project was a priority. (Maddie wiki 020309)

The average of all the “Object” element scores in the enactment rubric was calculated and represented in Figure 23. It shows the improvement in the enactment score (Object elements) from Iteration 1 to Iteration 2. As presented in the previous section, only six teachers were able to complete the second iteration, and teachers completed their iteration cycle at different points in the design, based on the school calendar. Again Bill received a lower enactment “Object”
score for Iteration 2 than he did for Iteration 1. This suggests that the lesson planning score (which paralleled these findings) is a possible indicator of the enactment of the lesson.

**Figure 23.** Enactment Object average score: Iteration 1 and Iteration 2

Teachers who received the higher lesson planning scores also had the highest enactment (Object) scores in both Iteration 1 and Iteration 2. Figure 24 shows the correlation of these two measures for teachers’ Iteration 1, which was significant, with $F(1,7) = 18.775$, and $p < .001$ (R squared = .728). This relationship was also significant for Iteration 2 (see Figure 25), with $F(1,4) = 88.203$, and $p < .02$ (R squared = .957). While significance is difficult to interpret because of the small number of teachers, the correlation is consistent with an interpretation that successful enactment is dependent upon good lesson planning.
In addition, teacher knowledge (i.e., the “Subject” node, as in Figure 8) can be correlated with “Object” enactment score. This is an expected relationship, based on the research literature, which argues that teachers who have more pedagogical expertise are better practitioners as seen
through their enactment. Figure 26 show that teacher knowledge (Subject) is correlated significantly with enactment for Iteration 1, with $F(1,7) = 17.590$, and $p < .007$ (R squared = .715). This correlation was also significant for Iteration 2 (see Figure 27) with $F(1,4) = 24.991$, and $p < .001$, (R squared = .862).

Figure 26. Correlation of enactment Object and Subject (Iteration 1)

Figure 27. Correlation of enactment Object and Subject (Iteration 2)
4.3.3 Analysis of the Use of Reflection (Tools and Rules)

Reflections conducted by teachers during their enactment of the project-based lesson were as influential as they were in lesson planning. Scaffolded teacher reflections were done after various enactment days and these are interpreted in the activity system as both a tool and a rule. The elements for “Rules and Tools” in the enactment activity system focused on student learning and explicit ways in which teacher could change his or her lesson in response to what was happening in the classroom (see Figure 28). Wiki reflections provided evidence for the scoring of these elements, from 1 (lowest) to 3 (highest), according to a rubric provided in Appendix D and averaged across the enactment days.

Figure 28. PBL enactment rubric coding schema (Tool/Rule elements)

The following are samples of scored excerpts for one of the elements in the “Rules and Tools” node, concerned with “Teacher reflects on enactment.” A score of 2, a teacher with limited reflection on enactment, illustrates the teacher commenting only on the process of...
project-based for the student. A score of 3, shows a teacher making connections between students’ understanding of science concepts (in depth) and the project-based approach.

**Rubric: Score of 1.** Response indicates limited reflection and comments about readjusting lesson.

*Excerpt:* would change it so there are fewer activities or more step-by-step instructions on the screen, would also like to give more time for planning their project, but our curriculum really doesn’t allow that kind of freedom since we’re covering 2 years’ worth of expectations into one, there needs to be some kind of hands on activity in between the different stages so students aren’t stuck to the computers the whole time—their attention level could be improved. (Frank INT 180608)

**Rubric: Score 2.** Response indicates some reflection and comments about readjusting lessons.

*Excerpt:* There was title there for it but it never appeared, and also ... so yeah, a more detailed (student) template, and try and be more clear in our expectations of what they need to have online versus not online. I gave them free reign there. Some guys used it well. Some guys didn’t use the wiki at all. They did what they had to do when we were in class, and then they went right to the power point and didn’t touch the wiki again. So, which I never said they couldn’t do, so I really couldn’t penalize them for it. But I think in that it’s the first year, if I were to do it again, I would specify. (Alex INT 220509)

**Rubric: Score 3.** Response indicates strong reflection and comments about readjusting of lessons.

*Excerpt:* I think I need to be more specific about what the scientific concepts are, (but) and in understanding what was expected in the podcast...I need to put this specifically into the lesson template and the assessment rubric...Even though I spent more time explaining what I
wanted in this class, ... the podcast didn’t have enough science; the last class (first iteration), once they got it, they seemed to be more creative (in their product), maybe, in what they did. Now, I haven’t seen the final product (of the student from second iteration), so maybe I’m jumping the gun. But, what I’m seeing just isn’t to the depth (understanding of science concepts) that the overall group did last semester. There are individuals who are doing some really good things here, but the overall isn’t quite to the level yet. It may come... I will need to make sure that these groups put in more information into the podcast. (Merle INT 2503008)

Reflection scores in the enactment cycle show improvements from Iteration 1 to Iteration 2, suggesting that teachers became more insightful about project-based lessons and technology implementations in their second iteration. Figure 29 illustrates the reflection scores after enactments in Iteration 1 and Iteration 2.

![Figure 29. Reflection average in enactment (Iteration 1 and Iteration 2)](image.png)
Teachers’ reflection ("Rules and Tools") score is correlated with their total enactment score for both iterations. Figure 30 shows the positive correlation for Iteration 1, significant with $F(1,7) = 26.337$, and $p < .001$, ($R$ squared = .790). Figure 31 shows the same relationship for Iteration 2, also significant with $(F(1,4) = 23.095$, and $p < .001$, ($R$ squared = .852). These relationships lend weight to the argument that teachers who reflect immediately after their enactment achieve better results and improve more between successive iterations.

Figure 30. Correlation of total enactment score and total enactment reflection (Iteration 1)

Figure 31. Correlation of total enactment score and total enactment reflection (Iteration 2)
Reflections made during their lesson enactment in Iteration 1 and Iteration 2 allowed teachers to understand more about the lesson and the technology implementation. Most teachers expressed some familiarity with the notion of reflection at the end of the enactment. And indeed it was often from these reflections that insights about possible lesson plan revisions (i.e., for the next iteration) would occur.

4.4 Teachers’ Knowledge Development

The previous two sections have demonstrated the value of considering practices like lesson planning and enactment as activity systems. The coding schemes allowed a mapping of several distinct kinds of data onto a rubric, 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 reflection.

One way to interpret knowledge development is by examining the teacher knowledge quadrants established earlier in the chapter. While teachers were placed in their initial quadrants via a separate coding rubric, 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 32, 33, and 34 place teachers in the knowledge quadrant diagram at their initial stage (i.e., Figure 8), and then 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.

![Teacher knowledge grids — initial (from Section 4.1)](image)

*Figure 32. Teacher knowledge grids—initial (from Section 4.1)*
Figure 33. Teacher knowledge quadrants post–Iteration 1

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. Nor do they make specific qualitative claims, such as that planning,
enacting, and then revising an inquiry science lesson while reflecting can help teachers achieve mastery levels of PCK. In other words, these quadrant representations are at best only relative to the measures within this study and should not be interpreted otherwise. Still, when taken together, Figures 32, 33, and 34 suggest an interpretation that this intervention did help teachers develop their craft knowledge through engaging in relevant, authentic activities.

4.5 Patterns of Enactment: A Detailed Comparison of Two Teachers

One interesting characteristic of project-based learning and inquiry learning in general is the student-teacher interactions that occur within a classroom during the enactment of any lesson (Krajcik & Blumenfeld, 2006; Slotta, 2004). Teachers must interact with student groups, asking questions about their ideas and facilitating new learning opportunities. They must decide when is the appropriate time to pause small groups for spontaneous lectures, or to introduce new ideas based on what they have recognized from student work. To better understand a teacher’s enactment of his or her inquiry lesson, it would be of interest to capture such patterns and represent them visually for purposes of coding or comparison.

Stuessy (2005) developed a methodology for representing the pedagogical characteristics of classroom instruction. She introduced an innovative graphical representation that displayed several important factors concerning both student and teacher activities. This allowed a symbolic representation of the flow of activities, the emphasis on small group or whole class instruction, the activities engaged in by students, and the qualitative nature of student-teacher interactions. Such a video coding system was adapted in order to allow some insight into the student-teacher interactions that occur within the classroom. This coding scheme, different from schema developed from activity theory perspectives, identifies specific small and large group interactions. Project-based learning focuses on student collaborations and interactions, and therefore using video to follow specific patterns such as teachers engaging in small group
interaction (SGI) for management or pedagogy, or large group interactions (LGI) for management or pedagogy, enables a more complete understanding about teacher project-based processes within classrooms.

The following patterns of video enactment will compare two teacher participants, Charlie and Merle (see Figures 35 to 39). These two teachers were selected based on their different patterns of approach during the first iteration. A coding scheme was developed to capture patterns of teacher interaction with small groups (SGI) versus the whole class (LGI) and several pedagogical foci, including pedagogical (Ped), logistical, and management (M). The video capture of one period of class time was divided into four general segments representing: (1) opening class activities; (2) work period activities; (3) work period activities; and (4) closing activities. Charlie’s enactment of his first video lesson, which occurred over a 5-day period, reveals distinctive patterns, as seen in the figures below.

**Figure 35.** Charlie’s video enactment Day 1—Iteration 1
**Figure 36.** Charlie’s video enactment Day 2—Iteration 1

**Figure 37.** Charlie’s video enactment Day 3—Iteration 1
Figure 38. Charlie’s video enactment Day 4—Iteration 1

The most obvious pattern involves the amount of time spent in small group interaction from day to day. Note that small group interaction refers to the teacher’s interactions with a small group of students (i.e., not just the fact that students are working in small groups). If the teacher had placed students into small groups, then gone to the back of the room to grade papers, this would have received a different code. The first day and the last day seem to have the least
amount of time devoted to small group interaction. The first day was spent not only in discussing the science concepts but also the project itself, so that small groups were not possible during class time. Day 4 shows that largest amount of time for small group interactions, as the project-based work for the students was well underway.

The next series of figures are of Charlie’s enactment of his second iteration of the video lesson (Figures 40 to 43). These images provide an interesting comparison, and a backdrop to the lesson planning and enactment analysis for this chapter, as they offer further evidence of practice changes within the classroom.

Charlie Enactment II - Day 1

Segment 4

Segment 3

Segment 2

Segment 1

Figure 40. Charlie’s video enactment Day 1—Iteration 2
**Figure 41.** Charlie’s video enactment Day 2—Iteration 2

**Figure 42.** Charlie’s video enactment Day 3—Iteration 2
Figure 43. Charlie’s video enactment Day 4—Iteration 2

Seen from this second set of video enactment figures is that there are changes in the level of small group interactions. From Day 1, Charlie seemed to incorporate more small group interactions, so that student groups begin to discuss and dialogue right away about the science topics (i.e., on Day 1). This teacher change in practice to include more small group interactions was also representative of a conscious effort from Charlie to listen to students, and to provide students with as much time as possible to organize their understanding about the science concepts. These patterns illustrate how the lesson plan revisions and reflections have influenced Charlie’s patterns of enactment from within his classroom.

The next series of video enactments illustrates Merle’s patterns of video captured enactment (Figures 44 to 47).
Figure 44. Merle’s video enactment Day 1—Iteration 1

Figure 45. Merle’s video enactment Day 2—Iteration 1
Merle’s video capture patterns differ from Charlie’s, suggesting that she immediately starts students off in small group interactions. These patterns of small group interactions between
teacher and students reflect Merle’s stated value of listening to student ideas about science concepts. For example, the video transcript below (Table 11) illustrates rich interactions between the teacher and one specific student group from Day 1, Iteration 1. In this excerpt from Merle Grade 12 Physics class. She is talking with one group of students about their podcasting project. The students discuss the concepts that they are choosing within the podcast project and during exchange, Merle recognizes that the students did not understand the concept of electromagnetism. She then provides the students with some of that background information and further directions. The enactment patterns also match with Merle’s high reflection scores, high lesson planning scores, and high enactment scores, suggesting that as teachers become more reflective about their lesson plan and enactment, their patterns of engagement with students shift to emphasize facilitation and student exchange.

Table 11
Sample of Video Excerpt Teacher–Small Group Interaction

<table>
<thead>
<tr>
<th>Sample: Small Group Exchange</th>
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</table>

**Student 1:** In our podcast can we just ask them to walk through the exhibit, like this is and give you the history…where you…So in our exhibit we would like to walk through the exhibit…

**Merle:** Yes, everyone’s project will be different. Some will ask people to try to see how the exhibit works, and they will say now try this, not try that. Others may not do any of this, they may explain something completely description.

**Student 2:** Ours exhibit will give basic stuff, like how the light turns on with the bike. So do we just explain how the light will turn on with electricity?

**Merle:** You could. You explain the physics behind that.

**Student 2:** You can say it is a bike—now try and bike backwards.

**Merle:** Well okay—what is the concept that you are trying to show from that exhibit?

**Student 1:** We are trying to show that how work can create energy that will create electricity.

**Student 2:** Like innovation, trying to find different ways to using electricity. Other than a light switch?

**Merle:** Okay so you are saying you can use electricity to turn on a light bulb but you have to do this to in order for this to happen. So this a new way to create electricity. Now is it really a new way to create electricity?

**Student 2:** Yes
Merle: Tell me.
Student 1: When you start peddling, it creates power, right?
Merle: Okay. [pause]…It turns something. What is it turning?
Student 2: A generator?
Merle: Eventually…It is generating electricity. This concept goes back to the Grade 11 physics concept of electromagnetism.
Student 1: We didn’t study this. We didn’t get to electricity in my physics class.
Merle: So you have …
Student 2: Okay we did a little bit, but it was in an exam review.
Merle: So did you talk about magnets and coils. Coils of wire, and the idea that if you move a magnet near a coil, electrons move within the wire and you can create electricity with a moving magnet. Or you can keep the magnet stationary and move the coil, you will get the same effect. So a moving magnetic field creates electricity.

Note. Transcript October 22, 2008.

Such processes serve to guide the teachers, scaffolding instructional process and helping teachers to move away from traditional lecture style teaching. The next series of figures show Merle’s video capture for the second iteration (Figures 48 to 51).

![Merle Enactment II - Day 1](image)

**Figure 48.** Merle’s video enactment Day 1 — Iteration 2
Figure 49. Merle’s video enactment Day 2—Iteration 2

Figure 50. Merle’s video enactment Day 3—Iteration 2
Again, Merle’s patterns of enactment, interpreted from these graphical representation of actions within the classroom, illustrate a strong commitment to small group interactions. The teacher walks around, talks within individual groups, listens to their ideas and uses their ideas to help them understand the concepts. It was evident from Merle’s reflections on lesson plans and enactment that she had a strong understanding of project-based learning and was excited to apply her understandings in the course of enactment. These graphical representations provide support for the interpretation of the Activity System coding by connecting it to actual events that occurred within the classroom, as coded from video.

4.6 Summary

This chapter has examined reflections with qualities in lesson planning and enactment. Written reflection revealed that teachers could identify and interpret important aspects of their lesson planning and enactment and to make those aspects more “real” by putting them into words. These words could be shared with their peers and mentor, or read subsequently by the teachers themselves (e.g., when they were going into lesson revision, they could read their
reflections taken during enactment). All but one teacher improved as they engaged in two iterations of lesson planning and enactment, which would be expected. It was interesting to note the correlation of scores of lesson planning and enactment with the reflection. In Chapter 5, the intervention of peer exchange will be examined, to find patterns in how teachers learn through lesson planning and enactment within a community.
CHAPTER 5:
COMMUNITY—IMPACT ON LESSON PLANNING AND ENACTMENT

The common interests and practices among participants define a community. The teacher-participants within this study became a community because they were committed to improving their practices, to introducing innovative technologies into their classrooms, and to improving their students’ learning. They were generally positive about the goal of establishing a kind of loose-knit peer-exchange community that used both online and offline components. And indeed, such a community was seen to grow throughout the study, benefiting from two design revisions that helped improve the online and offline methodologies. This chapter is organized into seven main sections looking specifically at the impact of community. The first section will give a general narrative about the development of the community. The second will outline the online components, such as community reflections on lesson planning and individual reflective responses. The third and fourth sections analyze the community engagement and community nodes (and their constituent elements) within the Lesson Design and Enactment rubrics, respectively, following the coding schemes previously outlined in Chapter 3. The final section discusses evidence that teachers learned from each other and that ideas emerged in response to peer exchange.

5.1 Engagement in Face-to-Face Community

While it is argued in Chapter 3 that there is always some level of community present within any teacher’s practice (e.g., school community, science department community), and that the mentor relationship within the first design phase should be considered as an important dimension of “community” within the activity system analyses, the formal aspects of the community intervention began with a face-to-face meeting in Design Phase II. At this meeting, nine teachers were invited to engage in discussion and reflective activities. The purpose of this
event was to orient all teachers to the notion that their lesson planning, enactment, and reflection would now be supplemented by exchange of some materials with peers, conducted within periodic online and face-to-face tasks. At the organizational meeting, the researcher provided an overview of the goals and rationale for a teacher community, including the prospect that those gathered might continue as a professional community even after the research was completed (indeed, they are continuing in the coming year to discuss their work, although no further data is being collected). Meeting formats were described in the Procedure section of Chapter 3. At the end of each face-to-face meeting, the mentor clarified what kinds of online contributions would be required of the teachers, and what kinds of support they would be able to count on.

There were four community meetings, all of which maintained themes of reflection, community engagement, and improvement of practice. In some communities, face-to-face meetings are essential, in part because they allow a different set of activities and exchanges than are possible in any online format. Additionally, the community meetings served to establish routines and set directions for participants’ activities. Teachers participated in brainstorming sessions, reflected on ideas, and discussed new strategies that incorporated technology meaningfully into their lesson structure. The meetings were held in the evenings, with the exception of one summer meeting, which was held in daytime hours. The length of each meeting was approximately four hours, and the opening exercises always included an introduction and opportunity for teachers to meet each other informally. Refreshments were a necessity for the meetings because of their length, and meetings became a point of pride and identity for the group. There was always a feeling of shared value at the face-to-face meetings, where the teachers expressed genuine appreciation about peer interactions, sharing of lesson ideas, and reflections. The teachers who came consistently to the meetings became the leaders, which had a clear impact on their level of enthusiasm in the other activities within this study (e.g., designing
and re-designing their own lessons). For instance, the teacher leaders gave suggestions re the
lesson design that were always adopted by other teachers. By the end of the project, the teachers
had solidified into a coherent, committed group and even decided that they would present their
work at the provincial science teachers’ association. Table 12 offers an overview of the
community meetings and activities.

Table 12

<table>
<thead>
<tr>
<th>Teacher Community Meetings 2008–2009</th>
</tr>
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<table>
<thead>
<tr>
<th>Community Meeting January 2008</th>
<th>Community Meeting February 2008</th>
<th>Community Meeting March 2008</th>
<th>Community Meeting April 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Names of participants</td>
<td>Merle, Maddie, Charlie, Olga, Frank, Alex, 2-Researcher(s)</td>
<td>Merle, Maddie, Charlie, Olga, Alex, Bill, 2-Researcher(s)</td>
<td>Merle, Maddie, Charlie, Olga, Alex, 3-Researcher(s)</td>
</tr>
<tr>
<td>Length of the meeting</td>
<td>4.5 hours</td>
<td>4.5 hours</td>
<td>4.5 hours</td>
</tr>
<tr>
<td>Activity Structure of the meeting (protocol)</td>
<td>Introduction, welcome</td>
<td>Review of last year’s work, individual reflections Video capture of class work (enactment) Curriculum plans for the year</td>
<td>Reflection sharing Lesson Plan Brainstorming (similar to last session) Exchange of new plans, ideas for the new term Student projects completed for this term</td>
</tr>
<tr>
<td>Themes (identified by research)</td>
<td>New concepts, educational technology, introductions</td>
<td>Curriculum, student learning, educational technology, community of practice</td>
<td>Reflection, student learning, educational technology, community of practice</td>
</tr>
<tr>
<td>Images of the Meetings</td>
<td><img src="image1.png" alt="Image 1" /> <img src="image2.png" alt="Image 2" /> <img src="image3.png" alt="Image 3" /> <img src="image4.png" alt="Image 4" /></td>
<td><img src="image5.png" alt="Image 5" /> <img src="image6.png" alt="Image 6" /> <img src="image7.png" alt="Image 7" /> <img src="image8.png" alt="Image 8" /></td>
<td><img src="image9.png" alt="Image 9" /> <img src="image10.png" alt="Image 10" /> <img src="image11.png" alt="Image 11" /> <img src="image12.png" alt="Image 12" /></td>
</tr>
</tbody>
</table>
It was not common for teachers to exchange strategies or materials outside their own school context, as admitted by teachers when they shared information during the meeting. However, most teachers appreciate and value professional discussion and dialogue. In the following excerpt from one of the face-to-face community meetings, several teachers were able to benefit from their peer exchanges in the design of a new lesson. Teacher peers and the researcher-mentor all offered suggestions and ideas for Alex (a new teacher-participant) to think about re his project lesson (Table 13).

### Table 13
**Sample of Face-to-Face Community Exchange**

<table>
<thead>
<tr>
<th>Sample: Rich Community Exchange</th>
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<tbody>
<tr>
<td><strong>Charlie</strong> (regarding project work using wiki technology for Grade 7 science classes): I don’t know. I would have to try it. Just my gut would be it wouldn’t be my first choice for things. They’ve given me very good computer design work. They’ve had to develop brochures for endangered species and do things and…it’s always turned out surprisingly good, I think, but…</td>
</tr>
<tr>
<td><strong>Alex:</strong> What I’m going to ask…with my Grade 7s, the project that I want to do with them is to have them conduct a presentation. It’s an open-ended project that we do on the Earth’s Crust Unit and it’s basically to teach them about the Earth’s geographical features and energy transfer and whatnot, and I send them on their way. They go to the library…I have a very open-ended sort of rough idea of what I want. I want a research project. I want it to be about anything and everything having to do with the earth’s crust anywhere in the world. And it’s a multimedia-based project, so I’ll have PowerPoint presentations. I’ll have videos. I’ll have whatever, and I’m trying to incorporate this wiki site into it. Short of just using it as a tool to communicate between them, I’ve seen that my Grade 7s will be able to utilize it as a tool to put together a project. And we’ve had our talks about our concerns. You being a Grade 7 teacher, and you being a teacher who also uses wiki, you could see that as being a possibility for…?</td>
</tr>
<tr>
<td><strong>Merle:</strong> If you have a template on the wiki that the kids have to fill in as they are building their project…so what are the additional ideas? I mean, I learned that through Cheryl [research-mentor]. It’s very helpful. It really directs them to what they need to do. I think a Grade 7 kid could handle that.</td>
</tr>
<tr>
<td><strong>Charlie:</strong> I think so too.</td>
</tr>
<tr>
<td><strong>Maddie:</strong> A simpler template.</td>
</tr>
<tr>
<td><strong>Merle:</strong> Yeah.</td>
</tr>
<tr>
<td><strong>Charlie:</strong> The thing about my new favourite part about the wiki is the comments thing I think. Where my students gave feedback on the others’ projects. And yeah, I’m just thinking if the Grade 7s could do that reasonably or not. I guess some could.</td>
</tr>
<tr>
<td><strong>Maddie:</strong> A simpler template.</td>
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<tr>
<td><strong>Merle:</strong> Yeah.</td>
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</tr>
</tbody>
</table>

*Note.* Transcript August 27, 2008.
The exchange in Table 13 illustrates the potential importance of community dialogue, in terms of the influence that it can have on teachers’ ideas about curriculum and assessment. The discussion centers on Alex’s design ideas for a multimedia presentation project in a Grade 7 general science class. The discussion among peers leads to several specific suggestions and comments, in particular that a wiki template could be used to provide students with a simple form of scaffolding as they create their open-ended projects. Merle and Charlie were both able to address Alex’s apprehension about the use of the wiki and his concern about the capabilities of Grade 7 students. Charlie also suggested another wiki feature, the comments tool to be used as a scaffold for peer review. Alex went on to incorporate these ideas as he created his lesson design and shared his students’ final project at the next community meeting. The emerging knowledge that became evident through such sharing of ideas was thus visible to all participants, and was often captured in online materials (see Section 5.2).

In the third design phase of the study, reflections, online supports, and face-to-face community procedures were all improved with more scaffolding specific for project-based and technology enhancements. For instance, a clear interface was created for interaction with better questions, and the scaffolding of the community tasks were more defined for the participants. This made the tasks easier to follow and allowed teachers to focus only on their responses. Moreover, all the teachers were more experienced with the general process, and they all knew one another socially. Teachers shared their lesson plans as well as samples of student work, and selected portions of their reflections to share, primarily from their enactment phase. The goal of this community was to provide added benefit to the activity systems of lesson planning and enactment. While teachers in this study were not able to visit one another’s classrooms (even when in the same school, this proved logistically challenging), the goal was similar to those of lesson study, a collaborative development and implementation of a prescribed lesson (e.g.,
Lewis, 2002), and learning circles, a structured, collaborative planning approach with goals and tasks (e.g., Riel, 1992). In several cases, we were able to share a videotape of classroom enactment, and in one case, a teacher (Maddie) actually adapted the lesson design from another member of the community (Charlie), benefiting directly from his reflections about how to succeed with the lesson as she translated it into another content domain and student age group.

Table 14, another community excerpt, illustrates how the community members exchanged ideas and supported each other about their lesson process:

<table>
<thead>
<tr>
<th>Sample of Face-to-Face Community Exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charlie: I’m throwing ideas at them, and I got a real buzz off that. I thought that was really neat. I don’t know if I could plan to have problems go wrong because of what it does. I mean, you might think it’s exterior to the whole thing, but I like what it does for the student-teacher relationship as a whole when those kind of “crises,” shall we say, sort of happen. Even though they are not learning Newton’s Laws at that moment.</td>
</tr>
<tr>
<td>Merle: They’re learning problem-solving. Sure.</td>
</tr>
<tr>
<td>Charlie: Yeah. And I’m sure there’s some physics going on behind the scenes somewhere that if I really looked hard for, I could find, but…I don’t know, it’s like people pulling together in a time of disaster.</td>
</tr>
<tr>
<td>Maddie: Did you ask your students what they thought of this whole project?</td>
</tr>
<tr>
<td>Charlie: Not explicitly. You might have something at the end where [when they watch the films] I come in and give them a little…include a survey at the end.</td>
</tr>
<tr>
<td>Maddie: Yeah, I asked mine [to complete a survey at end]. And they actually…they thought they learned a lot after they figured out how to use the wiki site, and the Mac users that had never used i-Movie before. A lot of them did learn it, and a lot of them looked like they were enjoying themselves towards the end. I had to stay back until 5:30 three nights…but, I was impressed how many of them were actually willing to do that on Friday…stay there until 5:30. Two groups actually stayed behind. I was impressed that they would actually do that. Even today they came in at lunch to finish.</td>
</tr>
</tbody>
</table>

*Note.* Transcript December 2008.

Overall, this community supported teachers in the exchange of artefacts and ideas about project-based lessons and technology. They were an active group of professionals who were familiar with one another’s lessons and experiences and discussed pedagogical approaches.
deeply when they were able to gather. Their interactions were consequential, affecting their lesson designs and providing feedback about enactments. Most importantly, teachers voted with their feet, returning to attend successive meetings even amidst their busy school year.

5.2 Online Community Exchange

The online component of the community consisted primarily of wiki with an accompanying website, providing a space for persistent and continuous knowledge for the teacher community to draw upon. The online space offered not only a digital resource for teachers, but also a virtual location for peer interaction related to teacher lesson planning and enactment.

Following other online spaces such as MERLOT (McMartin, 1997) and MSPnet Hub (Falk & Drayton, 2004), this study defined community membership according to participation: whether individuals contributed lesson plans, reflections, and comments on the site, and whether they engaged in exchanges (e.g., adding comments to one another’s postings). Because teachers were from several different school sites, the online component helped them connect across distances and asynchronously, in a fashion that was convenient for everyone. This was evident in mentor meetings with teacher-participants, because teachers were able to go back to the online components and see what was written and discussed about their lesson plan. The emerging online component of community was analyzed in terms of teachers’ content sharing and reflections.

5.2.1 Content Sharing

The layer of technology added to the 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 student learning. The following panel of four screen captures shows Charlie’s lesson plan (Figure 52) and his students’ digital
artefacts (wiki pages), which he posted in order for other teacher-participants to review (Figures 53, 54, and 55). Such sharing allowed other teachers to see how their peers had set up lesson plans and the ways in which their lessons 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. They could follow the changes made from Iteration 1 to Iteration 2, as well as his rationale for those changes, and see the resulting impact on student work.

Figure 52. Charlie’s lesson plan blank template—Iteration 1
Figure 53. Charlie’s student video project design—Iteration 1

Figure 54. Charlie’s student video project design—Iteration 2
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 for students to make sure that students documented what they were doing throughout the process. After enacting this version twice (with minor revisions in Iteration 3), Charlie made substantive revisions in Iteration 4, introducing a new open-source wiki platform and making the project sustainable after the research study was completed. The wiki site made the lesson design process visible, because every time Charlie revised his lesson plan, it was visible to other members of the community.

5.2.2 Peer Reflections on Submitted Artefacts

In addition to viewing their peers’ lesson plans and samples of student works, teachers participated in scaffolded community reflections. Figure 56 provides a screen capture of an online community exchange concerning Charlie’s contributed artefacts. Community members made comments about Charlie’s lesson designs, starting with the second iteration (there was no online community component at the time of Charlie’s first iteration). Figure 56 illustrates the

Figure 55. Charlie’s student video project design—Iteration 4

Charlie’s student video project design—Iteration 4
reflections that were offered by his peers about his lesson and their suggestions about scripting and student focus. Figure 56 suggests the possible benefits of such online community exchanges, including timely feedback to a lesson design and a persistent record of the transitions that lessons undergo. This is significant for teacher communities, because teachers often work in a vacuum with little opportunity for feedback or peer exchange. Teacher lesson plans that are only on paper or in a word processor document are limiting for a community. A web-based document such as that of the wiki lesson used in this study makes it easier to develop community knowledge.

Figure 56. Community reflections on lesson plans (comm27/08/08)
5.3 Teacher Engagement in Community

5.3.1 Supporting Reflective Discussions

Along with reviewing lesson plans, teacher participants also engaged in peer reflections, which were grouped into three main categories: (a) student knowledge; (b) project-based learning; (c) technology. Figure 57 shows a web page from the online community that was provided to teachers in order to help them understand the different categories of reflection, as well as to provide links to reflection pages.

![Reflections Capture II](image)

*Figure 57. Wiki pages that described the community reflection elements*

Figures 58 and 59 provide a sample of teacher reflections about student knowledge and the scaffolded peer-commentary. The ability to see not only lesson plans but also the reflections about those plans had implications for the individual and community in their understanding about project-based teaching and technology-enhanced learning. This meant that teachers not only saw revisions of the lessons but also saw the decisions that went into making those
revisions. During the meeting, teachers commented about the lesson revisions and this influenced their design. For example, very few lesson designs at the beginning of the study had included student-peer exchange as a step in the process. This was a major change in the lesson design of one of the participants. However, all the teacher-participants that were heavily part of the community meetings went on to included student-peer comments because of the scaffolded reflections. All teachers participated in such reflections, and we even used the online site during face-to-face community meetings to capture teacher reflections and comments (e.g., on lesson plans) during the meetings.

Figure 58. Sample of individual teacher reflections
5.3.2 Teacher Engagement

Teachers who had limited understanding of technology were able to see, through their engagement with the online environment, how scaffolding and the use of the various technology tools could have potential benefits within their own classroom. 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’ artefacts and reflections and supporting their participation.

A simple coding was performed concerning teachers’ participation within the online and face-to-face community elements. Participants were scored from 1 (lowest) to 4 (highest) based on a rubric that examined community engagement. The various elements identified within this rubric were as follows: (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 implicitly seen within these elements.
Teachers who scored 4 were those who provided lesson plans and student artefacts, discussed their strengths and limitations with peers, reflected on the challenges and strengths of their enactments, and shared their assessment and lesson revisions. Those teachers who scored 1 on community engagement did not participate online and contributed nothing to the reflections or comments within the portal. A score of 1 is warranted as a lowest possible measure, acknowledging that all participants did have some social and collaborative exchanges, at least with the mentor. There were two teachers who participated in the study only prior to the community being established who were also scored with 1. The face-to-face community involvement was scored and ranked in a manner similar to the scoring used for online participation. The data source was a simple quantity value of participation in meetings or online tasks.

Table 15 provides all scores and gives a brief explanation of the teachers’ participation in online and face-to-face activities. A complete rubric for scoring of engagement is also provided in Table 15. The sum of the two rankings is tallied, which will provide an interesting metric for correlation analyses below.
<table>
<thead>
<tr>
<th>Teacher-Participant</th>
<th>Face-to-face Engagement</th>
<th>Online Engagement</th>
<th>Total Score</th>
<th>Comment about Participant Engagement in Community (Only evaluated the number of times attending and items contributed in the community)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charlie</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>Attended every community meeting, and always participated online; shared artefacts, assessments, and reflections</td>
</tr>
<tr>
<td>Merle</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>Attended every community meeting, and always participated online; shared artefacts, assessments, and reflections</td>
</tr>
<tr>
<td>Maddie</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>Attended every community meeting, and always participated online; shared artefacts, assessments, and reflections</td>
</tr>
<tr>
<td>Olga</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>Attended 3 community meetings, and always participated online; shared artefacts, assessments, and reflections</td>
</tr>
<tr>
<td>Alex</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>Attended 3 community meetings, participated online, shared some artefacts and reflections and some participation online; shared some assessments</td>
</tr>
<tr>
<td>Frank</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Attended only 1st community meeting, and limited participation online; shared artefacts, assessments, and reflections (didn’t have a job next term)</td>
</tr>
<tr>
<td>Bill</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Attended only 1 community meeting, videotaped himself for one community meeting, limited participation online; shared artefacts, assessments, and reflections</td>
</tr>
<tr>
<td>Placido</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Attended only 1 community meeting, very limited participation online; shared artefacts, assessments, and reflections</td>
</tr>
<tr>
<td>Daryl</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Never attended community meetings, and no participation online; shared artefacts, assessments, and reflections (finished both iterations before community began).</td>
</tr>
</tbody>
</table>
Another two-dimensional grid (Figure 60) can position teachers in the two categories of online and face-to-face participation in the study. The teacher positions are obtained from Table 15 and represent the level of participation observed from teachers in each dimension. Further, an overall engagement score for participation or engagement in community can be obtained by summing the two dimensions. This allows a comparison of these simple engagement metrics with the measures obtained in Chapter 4 in the Lesson Planning and Enactment scoring (i.e., for the Community node). 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.

The next section will examine whether those teachers who appear in the bottom left quadrant of Figure 54 (low online and low face-to-face) are also seen to score lower than others on measures of lesson planning and enactment, and whether teachers who fell into the high

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**Figure 60.** Teacher engagement: Online and face-to-face
online and high face-to-face engagement quadrant scored well on the lesson planning and enactment. 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 from the earlier Lesson Planning rubric and Enactments rubric. 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.

5.4 Community Impact on Lesson Planning and Enactment

To evaluate the impact of the community intervention within this study, we can make use of the Community elements of the Lesson Planning and Lesson Enactment scoring rubrics, which were coded relative to the available community support for teachers (i.e., in any given design phase of the study). That is, if a teacher in Design Phase I—where there was very little explicit role of community, except for the interactions with the mentor—had made highly effective use of the mentor relationship during lesson planning or enactment, that teacher received a code of 3 in the relevant tool. Because the community elements were coded relative to the available community resources (i.e., some 3s were given, even in Iteration 1 where the community supports were impoverished) it is possible to obtain a measure of each teacher’s reliance on community during lesson planning or enactment by averaging their community element scores across all of their iterations. Sections below are based on this approach, where for each teacher, the Community element scores were averaged in order to obtain a single Community measure for that teacher (i.e., independent of which design phase the iteration fell within).
5.4.1 The Impact of Peer Exchange on Lesson Planning

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 61). Each of these elements was scored according to the rubric on a 1 (lowest) to 3 (highest) scale.

<table>
<thead>
<tr>
<th>Lesson Planning Rubric</th>
<th>Participant’s Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Project:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Category Label</strong></td>
<td><strong>Quality Range</strong></td>
</tr>
<tr>
<td>Selection or choice of content (PCK)</td>
<td>1-3</td>
</tr>
<tr>
<td>Subject bound to the strategy</td>
<td>1-3</td>
</tr>
<tr>
<td>TPC - understanding of technology and use of it to improve the project design</td>
<td>1-3</td>
</tr>
<tr>
<td>Object forming project-based index * all within lesson plan</td>
<td>1-3</td>
</tr>
<tr>
<td>Inquiry-Based project; Exposes students to relevant ideas</td>
<td>1-3</td>
</tr>
<tr>
<td>Building on student understanding</td>
<td>1-3</td>
</tr>
<tr>
<td>Active student involvement in the process</td>
<td>1-3</td>
</tr>
<tr>
<td>Teacher facilitation of project</td>
<td>1-3</td>
</tr>
<tr>
<td>Assessment of the PBL-project</td>
<td>1-3</td>
</tr>
<tr>
<td>Science concept taught</td>
<td>1-3</td>
</tr>
<tr>
<td>Type of Technology (video, wiki, ppi, etc.)</td>
<td>1-3</td>
</tr>
</tbody>
</table>

**Figure 61.** Lesson Planning rubric coding schema (Community element)

The following ranked excerpts illustrate the different coding scores for the element “Interaction with community.”
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 INT301107)

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 INT 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 INT 291008)

The average Community score was tallied for all teachers across their two iterations. Figures 62 and 63 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 62. Correlation of Lesson Planning score and Community average score I
\(y = 11.422 + 8.912x\)

Figure 63. Correlation of Lesson Planning score and Community average score II
\(Y = 21.575 + 7.737X\)
5.4.2 Peer Exchange on Enactment

Peer exchange influenced enactment of lesson plans, as teachers became aware about other teacher-participants’ projects and how they enacted them. The community meetings, the community activities, and peer discussions sparked appropriate reflections about effective project-based enactment with technology in science classrooms. The Community elements on the Enactment coding scheme focused on explicit interaction with community members. For example, one element was called “Teacher uses community ideas in enactment” (see Figure 64).

Each of these elements was given a score from 1 (lowest) to 3 (highest) according to a rubric provided in Appendix D. Distinguishing between score of 2 and 3 becomes important. A score of 2, shows some advice taken from but in a very simple way (e.g., management of lesson). A score of 3, shows advice taken in a more complex pedagogical manner to address project-based learning and technology.

<table>
<thead>
<tr>
<th>PBL Enactment Rubric</th>
<th>Participant's Name:</th>
<th>Cycle:</th>
<th>Type of Project:</th>
<th>Subject Discipline:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category Label</td>
<td>Quality score</td>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td>Setting the context of the lesson (explicit instruction)</td>
<td>1-3</td>
<td>How does teacher explicitly set the context for using the particular content-concept for the project work (PBL)? Clear instructions on PBL aims?</td>
<td></td>
</tr>
<tr>
<td>Ownership of the lesson (commit level)</td>
<td>How does teacher work through the elements of the lesson? What are some of the sustaining bricks? Does the teacher give examples for their project endeavor?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPKT - explicit and demonstrate technology and use of it to improve the project design</td>
<td>How does teacher explain the use of the technology within the lesson plan? Does teacher demonstrate the use of technology either to help the science content or help the project process?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capability of addressing the facility of the lesson</td>
<td>How does teacher pace the lesson and gauge student working through the lesson?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Group Interactions</td>
<td>How does teacher create and establish a collaborative work?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object</td>
<td>Teacher makes connections to student ideas during class</td>
<td>How does teacher connect to student ideas during class (addressing of prior knowledge)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equity-based project; exposes students to relevant ideas to themselves or others</td>
<td>What does the teacher do/examples they use in class to make the lesson more relevant to the everyday life (i.e., practical and authentic)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Based on student understanding within the class</td>
<td>What do teachers engage with students to hold on their understanding? Questioning, Encouraging? Monologues? Discussion? Other - e.g., go to resource websites?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enable-planned student activities (collaborations)</td>
<td>How does the teacher involve the student in the process of the project? What language do teachers use to encourage collaboration? How do they ensure that this process?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher achieves the objectives for teacher driven lesson plan (walking around, ask questions)</td>
<td>How does the teacher design specific scripts and rules for interaction in the project? (defines the areas in which teacher input is required; teacher plays a role in the process component of the lesson)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers implements planned assessment</td>
<td>How does the assessment of within the lesson plan? How does feedback impact the lesson enactment?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science concept taught (specific lecture)</td>
<td>What type of science emphasis does the teacher engage in during the lesson? Does the teacher teach a relationship between science to PBL or does the teacher teach in larger class?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of Technology chosen for the lesson; (video, wiki site (student); pp; LCD projects)</td>
<td>What types of conversations does the teacher have with students to enhance the project? What types of additional instruction does the teacher put within place for the lesson (i.e., lesson purposes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The lesson plan used within the lesson</td>
<td>How many times did the teacher refer to the lesson plan? How did they implement the lesson?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool/Rule</td>
<td>Teacher reflects on enactment</td>
<td>How productive was the reflection? Did the teacher adjust or redesign their lesson plan based on the actions from the class?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher reflects on student learning through the lesson enactment.</td>
<td>How does teacher recognize student learning during enactment and the importance of the learning - enactment?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Able to demonstrate after the lesson - how would they change - during the lesson (i.e., examples of change because of the reflection metacognition)</td>
<td>How did teacher use the evidence of the enactment to help them enact the lesson next time? Specific with technology, with tech helped in the lesson enactment.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Div. of Labor</td>
<td>Teacher uses community ideas in enactment</td>
<td>How does the teacher use community advice within their delivery of the lesson?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community Influence of Community</td>
<td>How did the community (peers) influence their enactment/lessons (lesson planning scripts)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total and Comments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 64. PBL Enactment rubric coding schema (Community elements)*
The following excerpts illustrate the different coding scores for the element “Teacher uses community ideas in enactment.”

**Rubric: Score of 1.** Response shows limited use of community advice within their delivery of the lesson.

*Excerpt: [Participant writes not applicable] N/A (Daryl INT 290508)*

**Rubric: Score of 2.** Response shows some use of community advice within their delivery of the lesson.

*Excerpt: We did take the time to go over how to navigate through and perhaps this took some class time away. This was kept to a minimum (about 30 minutes) and Cheryl [researcher] was there to help them through. In addition, I did go over a PowerPoint to describe the assignment, which took about 20 minutes. I don’t see this as a problem because it integrates well to the course. There were problems of deleting because when they post and make an error they are not permitted to move or delete mistakes, so it took time to wait to ask. My expertise is still minimal and I also don’t have rights, so they needed to speak directly with Cheryl [researcher]. (Olga wiki 240908)*

**Rubric: Score of 3.** Response shows strong use of community advice.

*Excerpt: (Charlie referring to student template and enactment)...Can we change this? Not “do you have any suggestions” but “include your suggestions for communication.” How about just those four? That’s fine. So I need to add that to the wiki somehow. Can we have a template for the discussion? ...Yeah. I have a template for the discussion, but also I think what Merle did was just to tell them to copy it and paste it from the template section, which worked just as well. So, but I know that it was effective. Did you see Merle? Merle used the wiki site also for podcasting and she had them do the same thing you did, which is give each other feedback, and she really liked that because what happens is that was the first time that they were able to*
speak out loud their script? And once they were speaking out loud, they realized that they weren’t explaining it, or explaining it properly. Which may not be a bad augmented thing...It's kind of a cool idea. (Charlie wiki 070509)

Teachers with higher overall community scores also had higher total enactment scores. Total enactment score for teachers’ first and second iterations were correlated with their total Community score, as shown in Figures 65 and 66, respectively. The correlation of these measures for Iteration 1 (Figure 65) was significant, with F(1,4) = 7.662, and \( p < .05 \) (R squared = .657) (\( Y = .485 + .631X \)). The correlation of these measures for Iteration 2 (Figure 66) was also significant, with F(1,4) = 29.944, and \( p < .005 \) (R squared = .939) (\( Y = 33.423 + 8.749X \)).

*Figure 65. Correlation of total Enactment score and Community average Iteration I*
This suggests that community discourse and interactions could influence teachers’ efficacy of enactment. In addition to sharing artefacts, teachers reflected within the online community and gave and received feedback, which also had an impact on how their lessons were enacted. Such community exchanges fostered more student collaboration, greater awareness of how project-based lessons are implemented effectively within a classroom, and greater use of technology as a scaffolding tool within the teachers’ lessons.

5.5 Validating Measures of Community Engagement

The engagement scores tabulated in section 5.1 were obtained through a coding of face-to-face and online engagement that was conducted independently of the initial scoring of the Community elements in Tools 1 and 2. Therefore, the engagement measure from section 5.1 can be used for validity checking against the Community’s element scores from the Lesson Planning and Enactment coding schemes. While it seems intuitive that the two measures would align, it is still an interesting comparison to perform. The Community element scores from the Activity System coding schemes represent how the teachers used community interactions within their
lesson planning or enactment. The community engagement score represents the teachers’ commitment as gauged through the time and effort they spent in online and face-to-face activities.

Figures 67 and 67 show that teachers with higher community engagement scores also scored higher in the Community elements for lesson planning and enactment, respectively. The correlation of engagement and Community in lesson planning is significant, with $F(1,7) = 19.688$, and $p < .005$ (R squared = 0.839). The correlation of engagement and Community in enactment is also significant, with $F(1,4) = 29.944$, $p < .005$ (R squared = 0.939). This suggests that perceived community engagement was related to the role of community in the lesson planning and enactment activities.

*Figure 67. Correlation: Community average (Lesson Planning) and Community Engagement*
This section provides some illustrations of the impact of the peer community on the lesson planning and enactment of individual community members. Based on the criteria of project-based lessons established at the start of the research study, Charlie’s project, for example, initially had some missing elements, such as a focus on specific science concepts and scaffolding for students’ learning. However, through a series of iterations, Charlie revised his design and reflected on his experiences in enacting the lesson. Other members of the community benefited from this, as they were able to see the various revisions of Charlie’s work as well as his reflections on the various changes. Two versions of his lesson, together with his reflections, are summarized in Table 16.
<table>
<thead>
<tr>
<th>Charlie—Video Project, Physics</th>
<th>Charlie—Reflection on Revision</th>
<th>Researcher Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Sound—Guitar Hero Henry!</strong></td>
<td>“The main focus of this first cycle was to allow the students to do something fun. I would like to have something that I will be able to show other students in the years to come, that will inspire students, but also to make physics more accessible to them. By having students community their ideas to other students this can happen” (<em>Int: 21/02/08</em>)</td>
<td>There was no set assessment for this assignment. The project was almost seen as trial in approach and design. Problems that were anticipated such as student editing knowledge and student videotaping did not arise.</td>
</tr>
</tbody>
</table>

| **Unit Electromagnetism—Student Template (includes student log)** | “The second cycle improved the design by following the students as the planned their video. The journal logbook was introduced—which we talked about in the first cycle design but somehow got left out. However, these projects were okay. But some problems arose. Students that saw other student projects were somehow influenced by the design. The projects became more about the story than about the physics. The videos become longer, and the students also did not show me their work during the process—so in some cases I had no idea what the students were working on” (*Int: 29/05/08*) | In this second cycle of design. The logbook was introduced, indicating a shift in design to accommodate the tensions created in first design. However, the overall project still missed critical elements of project design. The students were creative but missed the objectives of project. Timelines of the video were not met (i.e., the videos were too long) and students decided to develop character and plot, missing out on the science concepts. This project had more value to the students as this was seen as part of their culminating mark. And also made the teacher realize that early scaffolding using the wiki site was essential in the project development. |

The peer community established in the second design cycle supported the new teachers who joined the community by providing examples of how the existing teachers’ lessons were implemented, guiding these teachers in developing their own designs, and offering practical examples of student learning through the final student artefacts.

The detailed wiki lesson designs, reflections, and revisions inspired one younger member of the community, Maddie, to review other teachers’ design process, and even adapt another teacher’s design as the basis of her own first lesson. In this case, Maddie chose to use Charlie’s
video lesson as a basis for her own lesson design. She incorporated Charlie’s most recent improvements in her lesson design after discussions with Charlie and the mentor about the various elements and processes of the lesson. This story illustrates the potential value of peer communities in general and, more specifically, of persistent wiki-documentation of lesson designs. All members of the community were able to see the evolving lesson plan, as well as the rationale for changes made to the plan. The online and face-to-face community enabled teachers to share resources and changes in the resources, as well as their reflections about the resource development and student learning.

5.7 Summary

Only through careful and conscientious support was it possible to get nine science teachers to participate in such a project, including the in-service planning and enactment of curriculum lessons, and the regular reflections and peer exchange. It is rare to achieve such a sustained level of focus and commitment from teachers when they are embedded deeply in their school years (Fishman, Marx, Best, & Tal, 2003). In this case, teachers actually developed innovative lessons, enacted them in their classrooms, reflected on evidence from student achievement, and revised the lessons accordingly. Moreover, they did this intentionally within a community of peers—offering and receiving critical feedback, sharing lesson plans, and commenting on one another’s reflections. The findings of this chapter reinforce the interpretation that engaging in the authentic practices of lesson planning and enactment facilitated the development PCK, and that a peer community played a meaningful role in such activities.
CHAPTER 6:
DISCUSSION AND CONCLUSION

This study investigated the development of teacher knowledge as it occurs during in-service practices, as mediated by scaffolded reflection and peer exchange. This chapter will summarize the main findings presented in Chapter 4 and Chapter 5, with a focus on how the research questions were addressed. The implications for teacher professional development will then be discussed, as well as the limitations of the study. Finally, the chapter will conclude with a discussion of challenges and opportunities for future research.

6.1 Engagement in Lesson Planning and Enactments

The goal of this study was to explore the associations between teachers’ developing understandings of project-based learning and their engagement in practices that are relevant to that pedagogy. The activity system coding allowed an explicit investigation of the relationship between teacher knowledge, outcomes of the activities, and the two interventions of reflection and peer exchange. Chapter 1 introduced the following research question:

*How do the activity patterns associated with lesson planning, lesson enactment, and lesson revision contribute to the development of teachers’ pedagogical content knowledge?*

6.1.1 Engagement in Lesson Planning

Planning a science lesson offers many opportunities for teachers in the development of PCK. Importantly, effective lesson planning requires the convergence of content knowledge, which is at the centre of any good lesson plan, and pedagogical knowledge, which is essential to engaging students in an effective learning design (Grossman, 1990; Park & Oliver, 2008). In developing a project-based lesson plan, teachers must go through several distinct activities: first, they must come up with an interesting project topic and make certain that topic is connected to
the content learning objectives; next, they must schedule and outline appropriate guidelines for the students; finally, they must connect the project objectives to student learning and assessment. Often when teachers go through these processes, the reasoning behind their decisions is hidden from others and even themselves. Making this implicit process explicit proved challenging for this research but was essential in understanding PCK development.

Through engagement in the complex sequence of activities that comprise lesson planning, teachers engaged deeply with their existing ideas about content, student learning, and their own role as instructor in a project-based lesson. The measures of PCK developed within this study generally correlated with lesson plan quality. Moreover, teachers who improved in their lesson plan scores also improved in measures of PCK. The use of Activity System coding allowed a formal connection of teaching practices to the influences of scaffolded reflection and peer exchange. In particular, it was possible to demonstrate that the Subject nodes of the planning and enactment activities developed, reflecting a development of PCK. This measure improved for teachers who engaged more deeply in the activities and corresponded to an increase in the quality of lesson plans and enactments. Thus, an explicit link was created between teachers’ knowledge (PCK and TPCK) and the activities in which that knowledge is said to develop.

The measures developed in this study allowed us to follow teachers’ knowledge development as they designed their lesson from one iteration to the next. In Charlie’s first iteration, for example, his low scores on reflection suggest that he was not as deeply engaged in the activities as other teachers (such as Merle or Maddie). This corresponded with a lower overall score for his lesson plan, as well as for the Subject node of the Lesson Planning scheme, reflecting a lower measure of PCK and TPCK. As Charlie progressed, he made a conscientious effort in Iteration 2 to revise his lesson plan, adding structure and changing his own approach to the enactment. He revised his lesson to include scaffolds for student inquiry, such as by adding a
wiki “script” for his video project, as well as explicit instructions for student collaborations. Moreover, he connected his own actions (as outlined in the lesson plan) to these scaffolds, by scripting a role for himself to look at each student group’s video script. Corresponding shifts in enactment accompanied Charlie’s elaborated lesson plan, and he even used the wiki for purposes of formative assessment.

6.1.2 Lesson Enactment

Lesson enactment is another critical aspect of teacher performance, and another opportunistic set of activities in which to measure the development of PCK. Borko and Putnam (1996) comment on the challenges involved in supporting teachers when they make instructional changes, and how difficult it is for teachers to learn and enact. Lesson enactment can be seen as an orchestration of classroom activities in which the teacher engages in large group and small group interactions with students, with various kinds of pedagogical content within any given interaction (didactic, logistical, Socratic, etc.). Teachers enacting a project-based lesson must engage in a series of activities: preparation and logistics (e.g., making sure the equipment and computers are ready); outlining both content and material information for students; discussing the schedule and due dates, as well as all forms of assessments; setting up the goals of the lesson; providing any background content instruction; etc. Then, once the student groups begin working on their project, the teachers should walk around the classroom, observe and address each group, listen to the students’ discussion, and suggest ideas to help students with their project goals, or with relevant science content.

The enactment of such lessons offers another excellent opportunity to demonstrate changes in PCK. Between Iteration 1 and Iteration 2, all teacher-participants demonstrated improvements in the “Subject” node of the lesson enactment coding scheme (which reflects both PCK and TPCK). These measures were obtained from a set of measures including field
observations, teacher reflections (completed during enactment) and video captures of classroom enactments. This finding is potentially important, because classroom enactments are complex, involving many sessions, and are often difficult for researchers to follow and assess. The Activity System perspective allowed such complex, hierarchical sets of activities to be interpreted through a single overarching scheme, which allowed an analysis of teachers’ knowledge development. Further, the correlation between teachers’ lesson plan (Object) and enactment (Object) shows a definite link between the outcome of lesson planning and the outcome of enactment. In short, this study found that if lesson planning improves, then enactment improves as well, and PCK improves as measured by the coding schemes defined here. It is not enough to simply plan and enact a lesson. Teachers learn through these personally and professionally relevant activities, supported by their reflection on their own understandings, and especially if they exchange with peers along the way.

One teacher, Bill, was the lone participant who scored lower in Iteration 2 for lesson planning and enactment, than he scored in Iteration 1. To account for Bill’s poor scoring, one must only look to his own engagement with the study (e.g., participation in the reflections, community meetings, etc.). While Bill had extensive teaching experience and had taught the Grade 10 science course many times before, he didn’t follow the regular planning and enactment activities as did other teacher-participants. He did not engage in the reflections during lesson planning, and did not substantively revise his lesson plan. It was up to the teachers themselves to choose to spend time with the activities to produce a quality, scaffolded, project-based lesson plan and then to enact this lesson according to the plan. In Bill’s case, he simply did not have the time, or did not choose to engage in the interventions, and hence all measures of his planning and enactment suffered (mainly for lack of anything substantive to code). This does not mean that Bill took nothing away from these experiences, as he did participate in some meetings and
exchanges with me (as mentor-researcher). He is a veteran teacher and will clearly manage his own professional growth as most teachers do. For purposes of this study, however, the data available on Bill did not allow a rich portrayal of his activities or reflections, and hence could not reveal any real growth or development of PCK as it did for all other participants.

Two teachers’ interactions with students during enactment were followed more closely by coding the videotaped classroom sessions. Following Stuessy’s (2005) approach to discriminating between different patterns of classroom interactions, a coding scheme was developed that enabled a visualization of small group and large group interactions. PCK involves the specific understandings of the types of teacher actions within the classroom that aid in achieving project-based learning objectives. Since project-based approaches involve a rich blend of small and large group interactions, it was important to see how these patterns of interactions changed within a classroom period, over the course of the entire lesson, and between a teacher’s iterations of the lesson.

In general, an emphasis on whole class interactions would be expected at the outset of the lesson (i.e., on day 1) as the teacher oriented students, followed by an increasing emphasis on small group interactions. The content of such small group interactions was also of interest, i.e., whether teachers were offering logistical support, or (ideally) engaging in pedagogical exchanges with students. The two teachers observed showed clear progression in how they engaged with students, which is one of the most interesting and validating findings of the study. They literally changed how they engaged with their class, developing their own effective patterns of large and small group interactions. One interpretation is that the more intensive small group interactions teachers have with their students during class, the better the overall outcomes of (a) teacher learning about project-based approaches, and (b) teachers’ understanding of student learning of
the science concepts. This suggests an interesting avenue for further coding and analysis of the substantive corpus of videotaped classroom sessions, as discussed below.

6.2 The Benefits of Scaffolded Reflection

While some prior research (e.g., Barnett & Coate, 20045; Schön, 1987) has explored the role of reflection in teacher learning, there is a need for a more nuanced understanding of how reflection helps teachers develop new understandings. What kinds of reflection are the most effective? When is reflection the most helpful? Can technology scaffolds facilitate the reflection process? How can a mentor or peer engage with a teacher’s reflections to provide further help? This dissertation investigates the role of scaffolded reflections as situated within the teaching practices of lesson planning and enactment. It seeks to address the following research question:

*How does engagement in scaffolded reflection support the development of teachers’ pedagogical content knowledge?*

Reflection is an active form of learning, with the purpose of objectifying and conceptualizing one’s experiences (Roth, 2001). Building on earlier research that investigated reflection-in-action (Schön, 1987), this study engaged teachers in scaffolded reflections that helped collect teachers’ thoughts while also serving to guide the activities of lesson planning and enactment. Thus, the reflections offered teachers a means of both support and reflection. For example, teachers received the following reflection prompts as they prepared to enact their lesson: (a) Where do you think the students will be challenged? (b) What will you try to do with your time during the lesson? (c) What are some of the follow-up concepts that require setup during lesson? By responding to such targeted prompts, teachers were not only reflecting about student thinking, but also preparing for their own activities.

The design-oriented nature of this research served to improve the reflection prompts, as well as the timing of reflections over the course of the study. It should be noted that reflection
was not optional for teacher participants. They were continually asked to write down their understandings within the wiki site and were interviewed throughout the process of planning, enacting, and revising. Teachers recognized the importance of this intervention and knew that they would benefit from participating. Indeed, there was a metacognitive element to the process, because the act of reflection was often discussed between teachers and myself, and teachers often came to reflect on the process of reflection.

Chapter 4 demonstrated that qualities of reflection correlated with teachers’ individual knowledge development about lesson planning. Those teachers who engaged deeply with the scaffolded reflections during lesson planning showed improved scores in the overall lesson planning process, and improved lesson plans. The Activity System coding scheme allowed reflection to be isolated as the “Rule” node, and the lesson plan as the ”Object” node. This permitted the interpretation of reflection as an integral part of the overall Activity System, and allowed the coding and correlation of scaffolded reflections with the lesson plan for Iteration 1 and Iteration 2. In general, it was found that the better the quality of teacher reflections, the better the lesson plan, and the more visible the improvement in the lesson plan from Iteration 1 to Iteration 2. Thus, findings from Chapter 4 suggest that by integrating reflection into a lesson planning activity, teachers improve in the planning process and achieve better overall plans.

Not all teachers participated equally in the scaffolded reflections. Bill, for instance, had difficulty in writing down his reflections in any consistent way. There could be any number of reasons for this, but more importantly, the problem remains that when fostering reflection within a professional program, there is no set procedure that can be applied to every teacher professional (Hatton & Smith, 1995). Perhaps, as more teachers become aware of the direct links between scaffolded reflections and teacher knowledge development as seen in this study,
teachers could begin to participate voluntarily in scaffolded reflections as part of a self-improvement initiative.

The second major activity that was studied was lesson enactment. Chapter 4 also demonstrated that reflection strongly influenced teachers’ enactment of their lessons. The study followed a similar approach of embedding reflections into the enactment process, with teachers required to complete structured wiki pages before, during, and after their enactment. At each stage, the reflection questions targeted the pedagogical content knowledge that would be important for success. Again, the study interpreted reflection as a Rule and a Tool within the enactment activity system, and again there was an observed correlation between the teachers who were highly engaged in reflection and their success with enactment. The process of reflecting helped the teacher identify critical elements of the lesson, student conceptions, or instructional sequences, and informed their design of improvements to the lesson (i.e., in subsequent revisions). Thus, reflection led to an improved quality of the enactment of the lesson, and in turn, the improvements in enactment increased the quality of the reflections as well as the lesson plans.

Although it is difficult to measure teacher knowledge directly, this study was able to explore teacher understanding of project-based learning and technology through the lens of the teachers’ lesson planning or enactment. The reflections, along with field notes, lesson plans, and student artefacts, offered measures of teacher PCK and TPCK, allowing their placement on the knowledge quadrants grid (i.e., knowledge of project-based learning and TPCK). As the teachers moved through two cycles of lesson planning, enactment, and revision, teachers showed a clear trajectory toward the topmost quadrant for both project-based learning and technology. Thus, while the documenting the development of teachers’ pedagogical content knowledge is surely
elusive, this study helped reveal their learning as they progressed through a sequence of activities.

Reflection and the enactment of a science lesson can be seen as a dialectic process (Schön, 1983, 1987), where the classroom events such as students asking questions or experiencing difficulties feed into the teachers’ learning and knowledge, and vice versa. Thus, the complex nature of the science classroom influences the teachers’ development of PCK and the instructional strategies used within the classroom. Further, in this study, scaffolded reflective action involved not only well defined parameters but also included dialogue with peers. The next section describes how such community exchanges led to teachers’ success in the activities of planning and enactment, and hence to their development of PCK.

6.3 The Benefits of Community

As reviewed in Chapter 2, there have been previous efforts made by educational researchers to establish professional learning communities for in-service teachers (e.g., Schlager & Fusco, 2004; Smylie, Allensworth, Greenberg, Harris, & Luppescu, 2001). However, this is a very challenging endeavour, and more research is needed into the nature of effective community structures—both online and face-to-face—for practicing teachers. What should be the nature of interactions within such communities? How should they be led? What kinds of reward structure, incentives, or benefits lead to sustained participation? How do communities mature or evolve? What is their life cycle? What are characteristics of successful communities? This study sought to investigate a very controlled form of community that was designed in an evolutionary fashion so that it would fit within the intricate fabric of the various participants’ work lives and research activities. It addressed the following specific research question about community, although it has interest in all of the more basic questions listed above:
How does participation in a community of peers support the development of teachers’ pedagogical content knowledge?

Teachers can learn from each other. In this study, face-to-face and online exchange offered teachers an opportunity not only to view their peers’ lesson plans and learn about their peers’ enactments, but also to exchange ideas and opinions about how to improve those lesson plans and enactments.

Not all the teachers participated equally in community activities, and it was evident that teachers who were more active in the reflections were also those who would engage more deeply in the community activities as well. This leads to the empirical challenge in evaluating the effectiveness of community and reflection: Was it participation within the community that led to improvements in teacher reflections and lesson plans? Or was it really just a matter of co-occurrence—that those teachers who would have improved in such measures, no matter what, were also those inclined toward participation in the community? In this study, teachers who engaged in the community showed progress in their development of PCK. The ambiguity of “correlation vs. causation” is a fundamental challenge to any study of teacher engagement, and it is hoped that the present effort, by examining the detailed measures of participation, reflection, and various measures of PCK and TPCK, will provide some evidence that engagement in the community leads to benefits (i.e., even if it is only the motivated teachers who joined in).

Chapter 5 presented the finding that teachers who had high engagement in the community performed better in lesson planning and enactment than those with low engagement. A significant correlation was found between teachers’ level of participation in the community and their overall performance on both of those activities. While it may not be possible to formally determine any causal connection between those measures, the qualitative nature of this study allows a deeper description of the events that transpired within the community, which can
support an interpretation of a causal connection. For example, some teacher reflections stated explicitly that peer exchanges had helped them develop better lesson plans and understand their own lesson in new ways. This community could be described as a task-based learning community or a community of purpose (Schlager & Fusco, 2004). Community meetings were focused on discussions of project-based lessons and student outcomes. Following Schlager & Fusco’s model (2004), the community engaged in a structured set of interventions (i.e., reflection and peer exchange) to achieve a greater understanding about the design and implementation of project-based, technology-enhanced lessons.

Although it is difficult to determine the exact ways in which community exchange influenced teacher learning, the rich text and the examples do provide some evidence of this relationship. For example, suggestions offered by peers within the community were clearly important to a teacher’s revisions of his or her lesson plan. In the first iteration, with no real mechanisms for community exchange, the teachers’ lesson plans had limited emphasis on student exchange or collaboration. As the community matured, however, participants often discussed and critiqued this element, which led to a common emphasis on collaboration within teachers’ lessons. In all of their various project-based lessons, teachers began to recognize the value of student dialogue and peer feedback as part of the lesson design.

It was useful to place teachers’ engagement within the community on a two-dimensional grid of face to face (low versus high) and online (low versus high) participation (see section 5.3.2). Teachers notably fell into only two quadrants: either the “high” quadrant for both measures or the “low” quadrant for both measures. This suggests that some teachers in the study were simply more active and engaged altogether (as in the reflection intervention). Nonetheless, it was interesting to note the correlations of community engagement with the measures of the
Community node in the Activity System coding scheme—which reflected the influence of community on teachers’ planning and enactment.

Another finding presented in Chapter 5 is that the community allowed exchange of artefacts and approaches among participants. Maddie adapted Charlie’s video lesson plan, and Charlie and Merle had input into Alex’ design of his first lesson. These are discrete examples of transactions that occurred, which had a strong influence on the outcomes and experiences of some participants. While these exchanges were not studied formally in terms of measures and graphs, they are important anecdotal observations that led to insights about the function of the community.

Teachers within the community exchanged valuable feedback in their design of lesson plans and assessments, as well as anecdotal evidence about their enactment of project-based lessons. It shouldn’t be surprising that teachers learned from one another, as a basic premise of constructivism is that learning occurs through social exchange and knowledge construction with peers. However, such exchanges are often difficult for teachers to attain within the typical school context, and it is reassuring to observe evidence that exchange within a community of peers has significant impacts on teacher learning.

An interesting aspect of the design-oriented approach taken in this study was the introduction of a second cohort of teachers in Design Phase II, when new community supports were introduced amidst an established group of veterans of the study. This led to a phenomenon whereby enthusiastic teachers like Maddie and Alex, who came into the study expecting a community, were actually able to find one. This quickly reinforced the sense of stability and participation within the community, as Maddie and Alex lent their energy to the group. These relatively new teachers might not have been able to start up a community, but they were vital to propelling it forward. There is more work to be done in understanding the dynamics of effective
communities, but it seems from this anecdotal evidence that one could indeed deliberately establish a community for in-service teachers, with newcomers providing the level of participation that is vital to community sustainability. In Schlager and Fusco’s work (2004), participants were encouraged to trust each other, support each other, and then disseminate their knowledge to other teacher communities (e.g., within their own respective schools). This study had a similar pattern of engagement, where teachers trusted each other, supported each other through lesson design and enactment activities, and then shared their ideas within their own schools, as well as through a professional development conference for the wider science teaching community.

In one example of the influence of peer exchange, Maddie adopted Charlie’s lesson (in which students create their own video project about relevant science topics). She was able to see not only the revisions that Charlie made to his early versions of the lesson, but also see the reasoning behinds those revisions, by consulting some of the reflections that Charlie had provided within the community wiki. The actual process of reflection that Charlie went through during his lesson enactment involved his noticing that he had left out some critical aspects of the lesson plan during the first iteration. He had wanted to include more student journaling and he realized that although a wiki-student template was set up, he did not focus on this during his enactment. As Charlie set these his next iteration of the lesson, Maddie was able to incorporate them into her lesson plan as well. Her lesson template thus focused on students documenting their time during class and also ensured that students had completed the script for the video project prior to filming.

The intervention of community within this study can also be understood in terms of an Activity System perspective. Using the coding schemas and the formalisms of activity triangles, it is possible to represent the complex social system in which individual teachers can influence
their peers. According to the Activity System notation, the interaction between Charlie and Maddie that was described in the previous paragraph becomes explicit and illustrates a wider collection of nested relationships. Charlie’s “Rules” from his second enactment influence the Tools in Maddie’s first enactment. The new teacher, Maddie, benefits directly from Charlie’s revised lesson (wiki template) and Maddie sets about creating a student wiki template (Tool) that addresses not only Charlie’s suggestions for the lesson plan, but also includes Charlie’s approaches for this lesson plan.

This interaction between two participants is directly connected to the community meetings (face-to-face and online). The explicit exchanges of artefacts (e.g., lesson plans, student products, etc.) helped teachers develop in their knowledge and allowed some measure of their social knowledge construction. While most teachers typically do exchange resources with other teachers in their school, this study facilitated not only the exchange of artefacts (e.g., lesson plans) across schools, but also the reflections concerning the creative process that underlay those artefacts.

Furthermore, in the case of Charlie and Maddie, the comparison of Iteration 2 for Charlie and Iteration 1 for Maddie illustrates the sharing of ideas across a temporal space and how technology interfaces and scaffolds the community activities. This allowed for not only artefacts to be shared but also for ideas to emerge and become negotiated amongst peers.

It is also interesting to consider the community itself as an activity system—particularly as the peer community matured and as their technology environment evolved. Indeed, as the months of the study progressed, the community of teachers appeared to take on a level of autonomy and persistence, such that e-mail exchanges are still happening (even a year after the research was completed). Figure 69 illustrates an Activity System that describes a global activity
system for the teacher community within this study, in which many other activity systems are surely embedded and intertwined.

Figure 69. Adapted from Engeström’s Activity System—Peer Exchange Activity System

This research set out to make explicit connections between reflective processes, peer-exchange, and teaching practices. While the findings obtained are consistent with much of the prior research concerning reflection-in-action and peer learning, this study adds a deeper description of the various relationships and interdependencies, which can hopefully inform models for professional development. The next sections will outline implications for teacher professional development, which leads to many questions for future research.

6.4 Implications of Teacher Professional Development

If reflection supports the development of PCK and helps teachers become more metacognitive about their teaching processes, then reflection should be emphasized in teacher preparation programs as well as in-service professional development. Teachers should be encouraged to reflect, even about reflection—as a crucial professional practice that is the most expeditious means for them to develop pedagogical content knowledge. For example, the current
practice of having teachers submit lesson plans in order to document their coverage of content standards could be greatly enhanced by encouraging a reflection segment concerning the teacher’s understandings about how students will learn from that lesson, potential formative assessment opportunities, and what the teacher’s role will be in the enactment.

In addition, professional development should no longer be seen as an individual endeavour or experience. This study suggests that professional development was effective when it occurs within a community of practice. Shared experiences and dialogue amongst peers leads to new ideas about teaching and learning, and fosters direct changes to teachers’ practices (e.g., in adopting another teacher’s lesson plan or changing one’s enactment according to another teacher’s advice or experience). This study revealed that engagement within such a community was important to individual members in terms of their instructional activities, as well as to the overall collective body in terms of emergent norms and values. As teachers develop in their knowledge, a community of practice enables persistent forms of knowledge to emerge that become available to newcomers and veterans alike. For teachers to offer and receive critical feedback, share lesson plans, and comment on one another’s reflections within a community of peers is a very rare event. However, this study illustrates it can be achieved, and with some emphasis made by school leaders and professional development programs, could be sustained as an institutional norm (i.e., that, like reflection, teachers come to expect).

Lastly, the lesson plan and enactment rubric adds to the literature on teacher knowledge development by providing an analytic approach that serves to connect teacher knowledge to their participation in professional development activities. Most research investigates PCK in isolated ways, making its development difficult to follow (Park & Oliver, 2008). This study offered a way to connect PCK to teachers’ participation in two common teacher practices: lesson planning and enactment. By drawing on the Activity System notation, it was possible to observe the
relationships between teachers’ engagement in reflection, peer exchange, and professional practices, as well as the impact of that engagement on their own understandings.

6.5 Limitations of Study

This dissertation had a relatively small sample size, and although the study was longitudinal, the findings from the study are limited in their scope. At the very least, they should serve to illustrate possible ways to follow teacher knowledge development and to view teachers’ reflections and peer exchange in connection with their knowledge development. With a larger sample of teachers, more interactions and more community influence could be directly followed, leading to more distinct patterns of correlation between teachers’ engagement in the various elements and their professional growth. This of course would present new challenges, in that the data from such a study could become overwhelming and lose some of the rich contextual information that was seen in the present effort.

Within this study, verification procedures were employed to help confirm that all measures were trustworthy and credible. The qualitative data was evaluated and coded, and then an intercoder reliability check was performed for the coding schema. Still, the subjective and contextual nature of the research questions, along with the co-design process, could lead to uncertainty about procedures and data source selections. However, it should be noted that results were not perfect: not all participants improved with the interventions, supporting the authentic nature of the study and giving evidence to the need for a flexible model for professional development.

As the researcher of this study, my background as a science teacher had definite advantages and biases. The teacher-participants realized my role as a researcher but also appreciated my insights as a teacher. They welcomed my help and my advice on certain aspects of the curriculum in a co-design process. My close involvement within the design-based process
could have positively influenced the outcomes, (where teachers wanted to only please me as their colleague). However, the participation and commitment to this longitudinal study was evidence that teachers were engaged for their own professional development.

Finally, the impact of any community intervention is dependent on the members of the community itself. Within this study, the members of the community were self-selected as individuals who were interested in improving practice and technology-integration in their science class. The teachers were all generally quite involved within their school community and very knowledgeable about science content. However, although the community intervention was meant to foster their interactions, the heterogeneous nature of the members could be seen to affect the outcomes of the study. In fact, not all the participants were active in the same way, which leads to the realization that individuals within a research study or even professional development models have the choice to participate fully, in part, or even drop out. This suggests that professional development models will generally be quite dependent on the individual participants and their learning patterns. Any constructivist model of learning needs to be flexible enough to encourage individuals to learn at their own pace and time, and construct their knowledge based on their own needs. People cannot be forced to reflect, participate in community, or complete lesson plans and enact them, and the evidence from this dissertation should not be taken to suggest that they can be. These limitations suggest possible future research as described in the next section.

### 6.6 Directions for Future Research

Future research could examine a variety of questions that resulted from the present study, including several that could be addressed using the existing corpus of data collected here. The content of teachers’ reflections, for example, has been largely untapped by the present analysis, which focused on coding reflections in terms of PCK or other elements of the activity triangle. In
other words, the coding scheme served to abstract from content elements to achieve a qualitative measure of 1–3, but ignored semantic variables, such as what categories of student problems teachers were concerned with, or what strategies they would adopt. By examining the actual semantic content of the reflection notes, it would be possible to gain an even richer measure of the kinds of topics and issues that confront teachers during their planning and enactment, particularly concerning project-based learning or technology. It would be of interest to create a taxonomy of ideas that emerge from the teacher reflections, and use this to describe the unfolding understandings across the iterations and within the community.

An even greater asset for future research is the wealth of data captured within the videotaped classroom enactments. At least some portion of every teacher’s classroom enactment was captured on video, which was again largely untapped in terms of its potential for revealing patterns of interactions with students and pedagogical approaches. For example, a comparison of the actual enactment, inquiry activities, and student interactions could be made against that projected by the lesson plan, and described within the teacher’s reflections (i.e., what they said they would do versus what they actually did). This could be mapped onto an analysis of teachers’ conceptualizations in order to create a deeper understanding of the dependencies between knowledge and practice. The videotapes represent a rich dataset that could prove valuable to future research.

Another interesting aspect of this research has to do with teachers’ metacognitive understandings—particularly about the value of reflection and peer community. Throughout the study, frequent mention was made by the mentor about the value of these elements and their role in the treatment. Teachers also made occasional mention of the importance of reflection. However, no explicit treatment was given to teachers’ metaknowledge, nor was any formal analysis conducted to address this topic. Future research might address such questions.
In terms of professional development research, the interventions of scaffolded reflection and peer exchange suggest a model for professional development that could be studied further. This study demonstrated that these interventions had a long-term effect, significant commitment from its teacher-participants, and fostered the development of strong mentoring relationship (including some peer mentoring relationships that emerged). This peer community has continued to flourish as the teachers plan their professional development conference presentations, and continue to benefit from the studies outcomes, which informs their practices. One participant has even won an award for teaching practices within her local school board. Although no single type of professional development works for every teacher, this particular approach seems promising in terms of its capacity to help teachers adoption new pedagogical approaches and improve their practices. Important aspects of this model that could be further researched are concerned with teacher buy-in, as well as by the structured materials (i.e., the generic criteria of project-based, technology-enhanced lessons) and wiki scaffolds.

This study holds promise for professional development, supporting the view that teachers’ knowledge development is connected to classroom practices, with evidence that PCK develops through such practices when supported by reflection and peer exchange. The findings presented here can hopefully inform the design of in-service professional development models, perhaps best investigated through a sustained, ongoing community of practice for inquiry-oriented science instruction. Research should examine the most effective online community supports, reflection prompts and practices, and dynamics of community participation.
REFERENCES


APPENDIX A

Screen Shots of Website Sample Materials

**Home Page**

**Lesson Design Page**

**Wiki Lesson Planning Page (linked from Website)**
Teacher’s Sample Lesson Site

Teacher’s Lesson Template Site
Teacher Sample Video Capture of Enactment

Watch Our Movie

This is a short clip of work this term. Some of the important aspects to project-based learning to discuss - teachers’ facilitating projects.

Teacher Sample Video Capture of Enactment
Teacher Reflections Shared through Website

Sample of Teacher Community Reflections (about Chem’Myth’Try Busters Lesson Plan)
APPENDIX B

Interview Protocol Questions

<table>
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</tr>
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Timetable

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</tbody>
</table>

Generic Questions

1. What is your educational background?
2. How long have you been a teacher?
3. What subject disciplines have you taught the most of?
4. If you had to pick one vision for your lessons—what would it be?
5. What are you teaching this year? (optional)
6. What other activities are you involved with in the school? (optional)
7. How many teachers are in your science department? (optional)
8. How many teachers are in your school? (optional)
9. In general what are some reasons for your department would meet? How many times a year? (optional)
Interview Questions Protocol III (Questions are meant to understand teaching ideas regarding the project-based technology-enhanced lesson)

1. a. What are some of the ideas that your students bring to class (prior to the teaching of this concept (chosen concept)?
   b. How do those early ideas influence their learning during your course?
   c. How important is the issue of dealing with students prior ideas to your style of teaching. Please explain in detail using examples.

2. How do you make connections between the topics you teach and the real world? Give examples that are relevant to the students (and this concept)?

3. Why do you think, PBL is an effective way to get students to learn with the specific topic that you chose? What is it about your chosen topic that lends itself to PBL? What is it about your chosen topic that lends itself to technology enhanced Project-Based Activities?

4. a. What type of reflective process do you do normally regarding your lesson design, enactment and revision of lesson plan? What are the benefits or disadvantages of the reflective processes you experience during this research?
   b. What are some of normal community experiences you have with regards to your lesson design, enactment and revision of lesson plan? What are the benefits or disadvantages of the community processes you experience during this research?

Background (Wiki Questions)

1. What were some of the critical science learning moments for your own personal learning?
2. What are some of your visions within your science classroom?
3. In the topic that you are teaching, what are some important topics that you think are particularly challenging for students?

Learning and Teaching

1. What percentage of your class would you say is lecture-based, where you are on stage, talking to your students?
2. Besides lectures, what kinds of lessons do you teach in your class? (small group work? labs?)
3. What are some of the strategies you use to teach science?
4. Using a specific example from your teaching, how do you organize scientific knowledge?
5. How have you used computer technology in your teaching before?
6. What ideas do you have for computer technology that you would like to try out?
7. What is one lesson within your current science course that you feel is important and effective, in terms of how it helps students to learn?
8. How do you learn about what students are thinking during class?
9. How do you try to help make science seem relevant to students?
10. How do you make formative assessments that respond to students' ideas?
Project Based Learning

1. What do you think are the key elements of Project-Based Learning?
2. How do you think Project Based Learning can help (or not help) your science students?
3. What is one idea you have for a Project-Based Learning lesson that employs computer or information technology?
4. What would be the central inquiry question in that lesson?
5. What kinds of classroom management issues would you expect within the lesson?
6. What would your role be within the lesson? What kinds of interactions would you have with students, and what would the goal be for those interactions?
7. How would such a lesson be added into your broader curriculum? How would you set it up before hand and build on it afterward?

Lesson Design Strategy (Brainstorming and Scaffolding Template)

Developing a technology-enhanced project-based lesson for science students can be difficult and requires some thought. Think of a lesson or a topic that you have been dissatisfied with in the past. What were the difficulties in teaching this concept? How can technology and project-based learning help in covering this topic?

Determined topic

- Themes of project
- Why this topic or Theme?
- What is challenging for students (for this topic)?

How can technology help?

- What content or process would you like to address?
- What technology skills might they develop as a result of the lesson?
- What lifelong learning skills might the lesson give the student?

Possible technology resources

Lesson-activity structure

- What will students do, specifically, in what sequence?
- How will the lesson "play out?"
- What are some of the Project-Based features within the lesson design?

Pedagogical notes:

- How could teacher most effectively use her/his time in the classroom when kids are working on the project?
- What are some of the features in play to ensure that your objectives are completed?
- What are the strategies for follow-up?
- What are some of the details for the teacher as pre-lesson set up?

Possible links to other sources

Assessment
• List three concepts that you think will be the student outcomes from the lesson design
• How do you know that these concepts were learned?

Keywords
• List terms (words) (5-10 terms) that describe your lesson
• There are words or phrases that you would use to search your lesson with in a database
• e.g., science lesson

Specifics of This Research Project

The following will follow the experiences of science teachers (and their students) as they work through a Technology-Enhanced Project-Based (TEPB) activity or lesson within a science classroom.

Goals of Project

To understand how teachers' plan and organize technology-enhanced project-based activities.
To determine the relationship between teacher background, experience and co-design of PB activity
To determine the patterns of activity within the classroom
To determine the effect on student learning

Project-Based Learning

One of focus of this research is to investigate at the enactment of project-based learning. Project-based learning can be sometimes confused with problem-based learning (usually seen as PBL). Project based learning is designed to be used for complex issues that require students to think deeply about the concept. The issues tend to be authentic or real-world issues, student-centered and collaborative. Here is a list of elements for project-based learning.

Project-Based Learning Index

students work collaboratively
multidisciplinary
student-centred
culminating assignment (outcome based)
long term time frame
problem-focused

In addition, M3F project-based index includes (from above)
projects to be open-ended, allowing students to express their ideas
projects to have no predetermined answers.
collaborative environment, promote team-work
students to construct their own meaning
projects to integrate digital media that will reflect students' understanding of science concepts
projects to serve to share ideas between students and teachers
projects to have elements of innovative expression and artistic creativity
Here are some interesting sites regarding project-based problem-based learning

**Problem-based learning**
http://en.wikipedia.org/wiki/Problem-based_learning

**Project-based learning**
http://en.wikipedia.org/wiki/Project-based_learning
APPENDIX C

Research Consent Form (Teacher)

Dear Teacher,

My name is Cheryl Ann Madeira and I am not only a practicing science teacher, I am a doctoral student in science education at the Ontario Institute for Studies in Education of the University of Toronto (OISE/UT). I am at the point in my studies where I require the help of science teachers. As a requirement of my graduate program, I will work with a few science teachers. I will be looking at how technology-enriched science project-based lessons are created and then implemented. The project is under the supervision of Dr. Jim Slotta, my thesis supervisor at OISE/UT.

The University of Toronto Ethics committee has approved the study and School Name and School Board is aware of this research.

This study looks at technology-based project-based learning as one form of instruction that focuses on student problem-solving and meaningful learning. It also enables students to integrate a variety of subject disciplines (such as technology, art, media arts, and science). This study will observe one lesson that would normally be occurring in the science classroom with some innovative technology implementations. The lesson would be within the guidelines of the Ontario Curriculum. Student’s understanding of science will be followed throughout the process.

To help me understand the classroom process, I will be collecting data from the science class such as field observations, Wiki documentations, teacher interviews and responses, students project work, random student interviews (audio taped), and limited video documentation of the classroom activities. This data will help me understand the organization and the workings of a science classroom that is implementing technology-based project-based activities.

All data will be kept confidential. No teacher, student or school names will be used in any written or oral materials. Only my supervisor, Dr. Jim Slotta and myself will have access to the data. The data and consent forms will be kept in a locked file for five years until after this study is complete, at which time all materials will be destroyed.

There are no possible risks that are foreseen in your science class participation in this project. At any point during this study, the teacher and/or students can withdraw without any negative consequences.

I want to emphasize that your participation is completely voluntary. If you wish to participate, just sign below. If you have further questions please do not hesitate to call either myself or my supervisor (Dr. Jim Slotta).

Sincerely,

Cheryl Ann Madeira, BSc, BEd, MEd

CONTACT INFORMATION
Ms. Cheryl Ann Madeira
Doctor of Philosophy Candidate
Ontario Institute for Studies in Education
University of Toronto
Curriculum, Teaching and Learning
252 Bloor St., West,
Toronto, Ontario
Phone: 416 978 0069(b)
E-mail: madeirc@yahoo.com or cmadeira@oise.utoronto.ca
Dear Principal,

My name is Cheryl Ann Madeira and I am a doctoral student in the department of Curriculum, Teaching and Learning at the Ontario Institute for Studies in Education, University of Toronto (OISE/UT). I have also been a science teacher for 17 years. I am at the point in my studies where I require your help. I am delighted with the possibility of studying the science classes in your school as a requirement of my graduate program. My study will look at teachers’ understanding of project-based learning and technology-enhanced science instruction in relationship to their designs and enactment of project-based technology integrated curriculum. Students’ learning of the science topics will be followed as an ‘end-product’ of this project. This study is under supervision of Dr. Jim Slotta, my thesis supervisor at OISE/UT.

What issues does the study address?

This study will look at teachers’ understanding of project-based learning and technology-enhanced science instruction in relationship to the designs and enactment technology integrated curriculum. Project-based learning (PBL) is one form of contextual instruction that places the emphasis on student problem-solving and takes place over an extended period of time. Research has shown that this type of meaningful instruction that integrates a variety of subject disciplines enables students to defend and debate their scientific ideas. Technology can enhance PBL environments. The teachers involved in this study will be co-designers in the learning environment and the technology influences on PBL will be followed. The teacher-student exchanges within the classroom will be observed and connections between teachers’ background, project-based technology design and implementation, and student learning will be made.

What do I expect from the teachers and students who will participate?

The teachers were selected for this study based on their relevant teaching experiences, exemplary use of project-based activities, and integration of technology within their science classrooms. This study will design one lesson over the course of one curriculum unit. Using the Ontario curriculum guidelines for science, teachers will co-design technology-enhanced projects-based activities and then teach this curriculum. The student project-activities will involve group work. The process of teachers developing the curriculum and their teaching of the technology-enhanced science projects will be documented through teacher and student surveys, wiki documentations, interviews and limited videotaping.

What your teachers, students and your school have to gain from participating?

By participating in this study your school will be benefit from the development of curriculum that is customized for the students within your demographics. A total of 9 teachers from different secondary schools from the Greater Toronto Area will be involved in this study. Their collaboration and co-design of technology-enhanced project-based activities will address the new Ontario curriculum changes and establish innovative ways for delivery. In addition, teachers and students will benefit from the added technological support and the resources provided through this study. There will be a summary of this project submitted to your school to see some of the outcomes.

Will there be any risks for the students (or the school) associated with participating in the study?

There is limited risk for this study, as it will look at teachers, students and the classroom activities that are already naturally occurring. The video-documentation will be limited and will not be used for any other purpose except for this research analysis. Although videotaping can be seen as invasive, its use in this research will be incredibly important in order to see the how teachers teach within a technology-enhanced science classroom. Participation in this study is strictly voluntary and you can refuse to participate or withdraw from the study, at any time, without negative consequences. Your name, the school’s name, the teacher’s and the students’ name will not appear anywhere in the report or any paper.

Confidentiality has high priority:
All information that is collected during the interviews will be kept completely confidential. No reference will be made in written or oral materials that would link you to this study. Only my supervisor, Dr. Jim Slotta, and myself will have access to the audio and video tapes, Wiki documentation, surveys and student materials. The data and consent forms will be kept for five years in a locked cabinet in my office.

The University of Toronto's Ethics committee has approved the study. Furthermore, school board (_________) is aware of the project and agreed of its implementation into your school and science classes.

If you have any questions feel free to contact me by phone at 416-768 5156 (c) or by email cheryl.madeira@utoronto.ca or my supervisor Dr. Jim Slotta phone 416-923-6642, or by email jslotta@oise.utoronto.ca. We will be happy to answer any questions you may have and to discuss further details of the project. If you would like to inquire about the ethics procedure or participants rights, you can also contact the Ethics Office at ethics.review@utoronto.ca or 416 976 3273.

Please put one copy of the signed consent form in the attached envelope (the second copy is for your records), by ____________________.

Sincerely,

Cheryl Ann Madeira, BSc, BEd, MEd

CONTACT INFORMATION

Ms. Cheryl Ann Madeira  
Doctor of Philosophy Candidate  
Ontario Institute for Studies in Education/University of Toronto  
Science Department  
Curriculum, Teaching and Learning  
252 Bloor St., West,  
Toronto, Ontario  
Phone: 416 978 0069(b)  
E-mail: madeirc@yahoo.com or cmadeira@oise.utoronto.ca
Research Consent Form (Parent/Guardian)

Dear Parent/Guardian,

My name is Cheryl Ann Madeira and I am not only a practicing science teacher, I am a doctoral student in science education at the Ontario Institute for Studies in Education of the University of Toronto (OISE/UT). I am at the point in my studies where I require the help of your child. As a requirement of my graduate program, I will be working with your child’s science teacher, Name. I will be looking at how technology-enriched science project-based lessons are created and then implemented. The project is under the supervision of Dr. Jim Slotta, my thesis supervisor at OISE/UT.

The University of Toronto Ethics committee, the Board of Education and Secondary School is aware of and has approved this study.

This study looks at technology-based project-based learning as one form of instruction that focuses on student problem-solving and meaningful learning. It also enables students to integrate a variety of subject disciplines (such as technology, art, media arts, and science). This study will observe one lesson that would normally be occurring in the science classroom with some innovative technology implementations. Your child’s understanding of science will be followed throughout the process.

To help me understand the classroom process, I will be collecting data in your child’s science class such as field observations, surveys, Wiki documentations, students project work, random student interviews (audio taped), and limited video documentation of the classroom activities. This data will help me understand the organization and the workings of a science classroom that is implementing technology-based project-based activities.

All data will be kept confidential. No teacher, student or school names will be used in any written or oral materials. Only my supervisor, Dr. Jim Slotta and myself will have access to the data. The data and consent forms will be kept in a locked file for five years until after this study is complete, at which time all materials will be destroyed. There are no possible risks that are foreseen in your daughter’s/son’s participation in this project. At any point during this study, your child can withdraw without any negative consequences for her/his marks. Your daughter/son can review any of the transcripts or the responses to make changes or to add any information if required.

I want to emphasize that your child’s participation is completely voluntary. If you wish your daughter/son to participate, just sign below. If you have further questions please do not hesitate to call either myself or my supervisor (Dr. Jim Slotta).

Please put one copy of the signed consent form in the attached envelope (the second copy is for your records), and ask your daughter/son to drop it off in the sealed box in the school’s main office (or give to the teacher) by DATE.

Sincerely,

Cheryl Ann Madeira, BSc, BEd, MEd

CONTACT INFORMATION

Ms. Cheryl Ann Madeira
Doctor of Philosophy Candidate
Ontario Institute for Studies in Education/University of Toronto
Curriculum, Teaching and Learning
252 Bloor St., West,
Toronto, Ontario
Phone: 416 978 0069 (b)
E-mail: madeirc@yahoo.com or cmadeira@oise.utoronto.ca
Research Consent Form (Student)

Dear Student,

My name is Cheryl Ann Madeira and I am not only a practicing science teacher, I am a doctoral student in science education at the Ontario Institute for Studies in Education of the University of Toronto (OISE/UT). I am at the point in my studies where I require your help. As a part of my school program, I will be working with your science teacher. I will be looking at how technology-enriched science project-based lessons are created and then implemented. The project is under the supervision of Dr. Jim Slotta, my thesis supervisor at OISE/UT.

The University of Toronto Ethics committee has approved the study and the your School is aware of this research.

This study looks at technology-based project-based learning as one form of instruction that focuses on student problem-solving and meaningful learning. It also enables you to integrate a variety of subject disciplines (such as technology, art, media arts, and science). This study will observe one lesson that would normally be occurring in the science classroom with some innovative technology implementations. Your understanding of science will be followed throughout the process. There will be no marks associated with participating in this research.

To help me understand the classroom process, I will be collecting data in your science class such as field observations, surveys, Wiki documentations, students project work, random student interviews (audio taped), and limited video documentation of the classroom activities. This data will help me understand the organization and the workings of a science classroom that is implementing technology-based project-based activities.

All data will be kept confidential. No teacher, student or school names will be used in any written or oral materials. Only my supervisor, Dr. Jim Slotta and myself will have access to the data. The data and consent forms will be kept in a locked file for five years until after this study is complete, at which time all materials will be destroyed.

There are no possible risks that are foreseen in participating in this project. It will give you insight into a “real” research project and what social scientists do. At any point during this study, you can withdraw without any negative consequences you mark.

I want to emphasize that your participation is completely voluntary. If you wish to participate, just sign below. If you have further questions please do not hesitate to call either myself or my supervisor (Dr. Jim Slotta).

Please put one copy of the signed consent form in the attached envelope (the second copy is for your records), and drop it off in the sealed box in the school’s main office by Date.

Sincerely,

Cheryl Ann Madeira, BSc, BEd, MEd
APPENDIX D

Rubric: Initial Teacher Understandings of Project-Based and Technology-Enhanced Lessons

* For purpose of grid (-3 to +3) Responses below from pre-interview

<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>
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<tr>
<td>Charlie</td>
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<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>
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<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 1</td>
<td></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>

**Project-Based Learning**

**Rubric: Low.** Answer has no relevance to project-based learning.

*Excerpt: Design your own lab would be an example, not restricted to classroom content, hoping that the students will remember better (Charlie INT 101007).*

**Rubric: Medium.** Answer has limited reference to project-based learning.

*Excerpt: Project-based learning is open-ended with more time, but finds the interests of children. Can move from individual work to more collaborative (Olga INT 060508).*

**Rubric: High.** Answer has strong relevance to project-based learning.

*Excerpt: I think it’s a technique. I think it works for a lot of kids. But there are some who just like to learn from the book. But project-based learning is really hands on learning and so they’re having to manipulate things, use different areas of their brain, be more creative...They are working with other people, so they are gaining knowledge from other...*
people’s ideas and experiences. The interaction...really help them learn as well. (Merle INT 060508).

Technology-Enhanced Learning

**Rubric: Low.** Answer has no relevance to technology-enhanced learning.

> Excerpt: Using PowerPoint to help students work on presenting concept. I don’t think students will know how to use PowerPoint...Students can use computers and technology, students can use the internet and make a PowerPoint... I just want a final product of 7 slides...pictures can be used (Daryl INT 101007).

**Rubric: Medium.** Answer has limited reference to technology-enhanced learning.

> Excerpt: Using the technology will help to manage the projects and figure out who is working (Maddie INT 291008).

**Rubric: High.** Answer has strong relevance to technology-enhanced learning.

> Excerpt: Using WISE system, helps focus on ecology of wolves. Having students come up with final news report either just audio or video using computer screen to film. Following the WISE custom authoring, helped make the project more Canadian. (Frank INT 040408).
### Rubric: Lesson Plan Exemplar Statements

<table>
<thead>
<tr>
<th>Activity Node</th>
<th>Element</th>
<th>Rule</th>
<th>Example Statements of Evidence from Lesson Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subject</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 1.                     | Selection or choice of content (PK)          | 1    | Answer has no relevance to the subject and PBL  
  *e.g.*, following along with the physics unit of energy resources (*Daryl Wiki 130508*)                                                                                                                                                                     |
|                        |                                              | 2    | Answer has limited referencing to content-concept and PBL  
  *e.g.*, I was able to look at expectations and determine my goals. I wanted to accommodate some of the curriculum expectations. You now cannot bring things into the school (e.g., household products—like bleach, Javex) cannot be seen at school. (*Bill Wiki 210509*) |
|                        |                                              | 3    | Answer is strongly connected to content concept and PBL  
  *e.g.*, Such a lesson would allow the students to interact with their peers not only through oral communication but by the use of technology (wiki) which would hopefully enhance their communication skills. With these skills and more “hands on” projects such as making videos of Newton’s Laws from start to finish would hopefully allow them not only to develop technological skills but also to have a true, better understanding of the concepts they learn in class. I would set it up before hand by telling them my expectations of the project, once the project was complete, I would have an open discussion with the students about their experience with it. The completed project could always be referred to in the future to help them recall the concepts worked on at the time. (*Maddie Wiki 121208*) |
| 2.                     | PK bd/unbd to content                        | 1    | Answer is not connected to student learning of the science related to PBL  
  *e.g.*, So now this project can accommodate these ideas. Other goals include notifying experimental design, design your lab, identification of chemicals in their own space. The only thing they had to buy was a natural indicator (e.g., cabbage, etc.) it was a reasonable lab to do at home because of cost. (*Bill Wiki 130508*) |
|                        |                                              | 2    | Answer somewhat links student learning to PBL pedagogy  
  *e.g.*, I am getting a kick out of what the students are doing. There isn’t a lot of down time. Everyone is doing something actively or intently paying attention because they found it interesting. (*Charlie Wiki 290508*) |
|                        |                                              | 3    | Answer is strongly links student learning to PBL pedagogy  
  *e.g.*, So I identified all of them that were strongly physics based and presented the students with a list of those programs and they were to pick one of them, identify the curriculum expectations that link to that program and then find four to six exhibits in the Science Centre that connect to the program, and then develop a podcast around one. So the idea is that if a teacher was coming for one program, or a student was coming for ... let’s say there’s a program on Energy Transformations. So if they were coming for a program on Energy Transformations, they would also be directed to four to six exhibits that relate to energy transformation. And so the kid’s job is to essentially develop a walking tour, right, for those. So that’s their big project. (*Merle Wiki 041108*) |
| 3.                     | TPCK understanding tech and use with project | 1    | Answer has no relevance for technology within project  
  *e.g.*, none found (all teachers wanted to use technology-null)                                                                                                                                                                                                 |
|                        |                                              | 2    | Answer uses technology slightly to help project work  
  *e.g.*, *What technology skills might they develop as a result of the lesson? PowerPoint, presentation skills, communicating to the class what they know,* (*Daryl Wiki 101007*)                                                                                                                                 |
|                        |                                              | 3    | Answer demonstrates good use of technology throughout the project work  
  *e.g.*, I think teaching teachers how to use a wiki might be really good. Because we have that e-class … the Board has e-class, but it’s hard to access that from outside computers. The nice thing about the wiki is that you can access it from anywhere, anytime. (*Maddie INT 060608*) |
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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Object</td>
<td>4.</td>
<td>1</td>
<td>Answer is not really connected to student ideas (weak constructivism) e.g., They (student) had a pretty solid rubric, so it was easy to follow, so the concepts are there to follow (Olga Wiki 480408)</td>
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<td>2</td>
<td>Answer somewhat links student ideas e.g., Deep down, I prefer to work on a project on something that I have control of rather than rote learning. Today—non-busy work. Not just giving them something that they are not working on something to keep them busy. They are developing a pride on what they are doing (Charlie Wiki 071107)</td>
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<td>3</td>
<td>Answer is strongly connects to student ideas e.g., So, one put a little &quot;smiley&quot; emoticon. &quot;Oh, and don’t copy Mr. Brooks’ rap. Make it your own.” “Also, it doesn’t sound like you guys have planned very much yet, so start planning what you guys are going to say.” So yeah, they had just minimal writing, so they won’t get as good a mark for the effort that they put into the video plan, but ... and then we have people who were later doing their comments, who can then comment on other people’s comments. She says, “I agree pretty much with what everyone said so far.” So I guess she read everyone else’s before she posted hers. “I think adding visual interest, as Zany wrote is something you might want to consider, especially since everyone is not an auditory learner. Many are visual learners.” So anyway, I think you get the idea that after you can see why, after reading some of these, I didn’t feel that I had a whole bunch more to contribute as far as advice goes. (Charlie Wiki 040408)</td>
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<tr>
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<td>5.</td>
<td>1</td>
<td>Answer has little relevance to real world/science e.g., following along with the physics unit of energy resources (Charlie Wiki 050508 )</td>
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<td>2</td>
<td>Answer has limited relevance to the real world/science—but has some understanding that it has importance. e.g., They’re good thinking questions that they ask, and most of the questions that the students ask they want to know for themselves. How long does bacteria take to reproduce? How many times can a starfish reproduce asexually? It’s things that at least they are somewhat interested in. (Daryl Int. 012208)</td>
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<td>3</td>
<td>Answer is strongly connected to the real world/science e.g., Concept theme: To extract natural indicators from grocery foodstuffs; to identify and test products as acid or base indicators; to comment on storage, use, and disposal (sic) of household chemicals according to WHMIS and HHPS. (Bill INT 071107)</td>
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<td>6.</td>
<td>1</td>
<td>Answer has limited opportunities for building on student ideas (limited constructivism) e.g., They were not sure about the design of the event. They were hung up on form. How to get started?...was more of the problem. Problems such as videos or having too many photos, Teaching has to happen to facilitate the medium (technology); But not the science. This exercise is to allow students to experiment and fail. Part of the process, finding out what went wrong. The students had to figure out the difference between initial experiment and the next version. (Bill INT 071107)</td>
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<td>2</td>
<td>Answer somewhat links and builds on student understanding (constructivism seen—although in consistent) e.g., * Harry Potter—exemplified ideas from the first cycle. I wanted the kids to make something that was funny. Plus, in physics. Students often feels that the students doesn’t think they like theme. The student were on a Harry Potter kick from the beginning of the year. Harry Potter storyline and references were recreated and written cleverly. Characterization kept true to (not boring). Before you know it they are doing they are doing physics…..Pop culture, their own interests and physics squished in there. (Charlie Wiki 131208)</td>
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<td>3</td>
<td>Answer is strongly builds on student ideas e.g., misconceptions on the lesson or science concepts? I will answer with regard to the lesson... they might be inclined to think they must prove something is WRONG with their own evidence which can be very challenging. They might be overwhelmed if they don’t thoroughly understand what is being asked. (Olga Wiki 261208)</td>
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<tr>
<td>Object</td>
<td>7</td>
<td>1</td>
<td>Answer has no relevance for student involvement in the project-process. &lt;br&gt; <em>e.g.</em>, I like to give the students a general overview of the concept and highlight its importance and then mostly teach the skills involved. Students should display what they have learned by writing answers and display on the chalk board. I always try to avoid being the text book—my examples and metaphors do not come from the text book—the students have an impression that I do not open the text book and I like that. (Placido Wiki 033109)</td>
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<td>2</td>
<td>Answer has little student involvement &lt;br&gt; <em>e.g.</em>, I have a very open forum for discussion in my class at all times … I invite student questionning (sic) and help them feel comfortable enough to do so. (Alex Wiki 120808)</td>
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<td>3</td>
<td>Answer demonstrates student involvement important and necessary. &lt;br&gt; <em>e.g.</em>, Concept theme: (include your vision for this concept). Theme is for students to find a myth that interests them and ties in with chemistry and verify or dispute it. Objectives: To create genuine interest in the topics discussed this year and to bring a strong STSE connection to the units in Grade 12 chemistry. Many complain of chemistry being theoretical, but this will help them see the connections in topics that interest STUDENTS in topics that will always be up to date. In addition, the opportunity to do problem based learning with the use of technology is expected to help with enduring understanding and gives them a chance to have some fun and creativity with chemistry! (Olga Wiki 103108).</td>
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<tr>
<td>8</td>
<td>Teacher facilitation of project</td>
<td>1</td>
<td>Answer limited link to student ideas. &lt;br&gt; <em>e.g.</em>, They (student) had a pretty solid rubric, so it was easy to follow, so the concepts are there to follow. (Alex)</td>
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<td>Answer somewhat links student ideas &lt;br&gt; <em>e.g.</em>, Deep down, I prefer to work on a project on something that I have control of rather than rote learning. Today—non-busy work. Not just giving them something that they are not working on something to keep them busy. They are developing a pride on what they are doing (Charlie Wiki)</td>
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<td>3</td>
<td>Answer is strongly connects to student ideas &lt;br&gt; <em>e.g.</em>, So, one put a little &quot;smiley&quot; emotion. &quot;Oh, and don’t copy Mr. Brooks’ rap. Make it your own.” “Also, it doesn’t sound like you guys have planned very much yet, so start planning what you guys are going to say.” So yeah, they had just minimal writing, so they won’t get as good a mark for the effort that they put into the video plan, but … and then we have people who were later doing their comments, who can then comment on other people’s comments. She says, “I agree pretty much with what everyone said so far.” So I guess she read everyone else’s before she posted hers. “I think adding visual interest, as Zany wrote is something you might want to consider, especially since everyone is not an auditory learner. Many are visual learners.” So anyway, I think you get the idea that after you can see why, after reading some of these, I didn’t feel that I had a whole bunch more to contribute as far as advice goes. (Charlie Wiki)</td>
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<tr>
<td><strong>Object</strong></td>
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<tr>
<td>11</td>
<td>Type of Technology</td>
<td></td>
<td>Answer lacks relevance for embedded technology and student learning in project. e.g., working in groups, PowerPoint, research, teamwork, etc. (Daryl Wiki 130508)</td>
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<td>2</td>
<td>Answer has limited relevance for embedded technology and student learning in project. e.g., the drama—of the students (working) collaboratively. The students disagreement (where Charlie was not aware of). Students video editing (one editing)—no one complained about the length of time to edit—mostly about the equipment problems computer issue—was the only complained; playing the footage—importing. (Charlie 290508)</td>
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<td>3</td>
<td>Answer clearly demonstrates technology embedded use in lesson and student learning in project. e.g., Coming up with creative ideas. Using/having access to the technology necessary to complete this project. (technology helps…)Easier/faster communication. Very hands on/interactive, which can be enjoyable for a lot of students. (needs…) Access to computers, internet, digital cameras/videos and necessary computer software. (Maddie Wiki 281008)</td>
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<td><strong>Rule/Tool</strong></td>
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<tr>
<td>11</td>
<td>Able to articulate teacher-learning prior to 1st enactment</td>
<td>1.</td>
<td>Answer has limited teacher-learning seen in reflection. Limited evidence how lessons show student learning? e.g., Instruction is (for) the most part—because a lot of the instruction…is centred around me. Means that the kids are attentive and not conversing. They only write when asked to write. I don’t write much, because it takes away from any focus or attention I want them to have. (Bill wiki 201107)</td>
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<td>2.</td>
<td>Answer has some teacher-learning seen in reflection. Some evidence how lessons show student learning? e.g., More loving the ideas of how they are choosing to present or communicate the ideas of science. As a teacher, I strive to do this in my class so it is neat to see how they work on this project. High Value in entertainment. Physics is a mandatory part of it. If they appears to be minimized in the overall event it is replaced by entertainment. (Charlie wiki 140208)</td>
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<td>3.</td>
<td>Answer strongly illustrates teacher-learning. Illustrates how teacher uses the evidence of the lesson as a way to see student learning. e.g., Students are asked to take specific concepts in physics (e.g., energy transformations, Newton’s Laws, Light and Sound, etc.) that they have learned in Grade 11 and 12 and explain these concepts to younger students who don't have the same background. They need to have a solid understanding of the topic to do this. (Merle wiki 081109)</td>
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<tr>
<td>12</td>
<td>Able to articulate teacher-learning post 1st enactment</td>
<td>1.</td>
<td>Answer has limited understanding of how lesson construction could provide ways to view student learning, technology implementation, and logistics. (after enactment) e.g., Making classroom space—find I have to leave for various reasons; My favourite thing is still lesson when I (teacher is)am engaging, I find that during the class, I feel not as productive. I am walking around…not helping. (Charlie wiki 140208).</td>
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<td>2.</td>
<td>Answer somewhat links to how lesson construction could provide ways to view student learning, technology implementation and logistics. (after enactment) e.g., Facilitate! It will be a huge job to organize and stay on top of where they are flowing, because if I let them go on the wrong path they will spend much time going the wrong way which will have the opposite outcome—to unmotivate them (Olga wiki 131008).</td>
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<tr>
<td>3</td>
<td>Answer strongly illustrates how lesson construction could provide ways to view student learning, technology implementation and logistics. (after enactment)</td>
<td>e.g., As I walk around the classroom I will be listening to and engaging in conversations. I'm trying to determine the type of background the students have in the topic they have chosen, make sure they are on task, help to clarify where needed and generally act as a resource to point the students in the right direction. (Merle wiki 130309).</td>
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<tr>
<td>13</td>
<td>Able to articulate student learning prior to enactment (2nd X)</td>
<td>1</td>
<td>Answer has limited linking to student ideas and student learning. e.g., Well, it’s my first time doing it. You know I’m very forgiving. It’s timelines, not due dates. So, kids were aware of the timelines and so we tried, couldn’t get it, or couldn’t get organized or whatever, so they are still ... I set it up in such a way that there was enough leeway for them, knowing that ... recognizing that reality. Some of them ... it was good. For something like this it seems as though they need that. Last year I just said, “it’s due on this date.” My hope is that I’ll get a better product, but that always remains to be seen. (Bill INT 010508)</td>
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<td>2</td>
<td>Answer somewhat links student ideas and student learning e.g., The students were more engaged than before. They appreciated the project on-line, something new Beginnings were good—but once on their own was not as effective Step 1 process (week one, week two, etc.) adoption of timeline— Before—the open-ended aspect and it was okay—and the students didn’t work the same as before—efficient; Open-ended wasn’t a problem before—but the students were not as guided as before—but didn’t seem to be a problem. But when we start with technology templates they need to be more continuous next year. There were three parts for the presentation (wiki, presentation/PowerPoint, and video) ... it was a trend. Media—multimedia aspect became a part of the project If the wiki structured—they don’t need to the PowerPoint. Everything should be loaded onto the wiki site (for the next activity). (Alex Wiki 220509)</td>
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<td>3</td>
<td>Answer is strongly connects to student ideas and student learning e.g., What are some of the follow up concepts that require set up during lesson? (What are some of the follow up concepts that require set up during lesson? What are some of the science concepts that your think you will follow up with next class? What science concepts do think on initial observations went well (or didn’t go well)?) After the students had had some time to learn a new concept. I had them explain it to me to make sure they really understood it. What are some of the science concepts that you think you will follow up with next class? With this project, I would deal with the individual groups to reinforce any concepts that I felt were needed. I probably would not deal with this as a class. I think that the students picked their podcast topics based on what topics they have enjoyed in their science classes. They have used prior knowledge from Grade 9–12. (Merle Wiki 1405008)</td>
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<tr>
<td>Div of Lab/Comm</td>
<td>Interaction of mentor (or emerging leader) or community</td>
<td>1</td>
<td>Answer indicates limited mentor influences. Answer has limited use of mentor for technology. e.g., N/A (Daryl INT 301107)</td>
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<td>2</td>
<td>Answer indicates some use of mentor influences. Answer has some use of mentor for technology. e.g., sharing ideas, cooperation and working together, team building, working together, and trusting that everyone participates and puts an effort. (general impression with mentor) (Frank INT 280508)</td>
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<td>3</td>
<td>Answer indicates strong use of mentor influences. Answer has strong use of mentor for technology. e.g., 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.” (Charlie INT 291008)</td>
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<td>Influence of Community</td>
<td>1</td>
<td>Answer indicates limited peer influence. e.g., Community negligible—difficult for me to do that; I have been here a long time. Interacting with the community—I am the community—expert teacher within this group. (Placido INT 190208)</td>
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<td>Answer indicates some use of peer ideas. e.g. Community in this research can see if it is easy to follow and explanatory; tried it... Maria and Claudia (pseudonyms)—will look at it this time (briefly).—review for the first time; (reference to other teachers on staff). Had found the community reflection on my lesson—and made my amendments. (commenting on the online community responses from community activity) Community at home for the students—it was a good feedback and experience for me (Bill INT 190208).</td>
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<td>3</td>
<td>Answer indicates strong use of peer ideas e.g., Marta use of peer-lesson (…about community activities…) Oh, I think it’s great, because definitely, you learn about the different things happen at school, the disadvantaged, the advantages, whether technical or illogical or resources, it’s a very good idea. And you also realize that one school might have a lot of access to a certain technology versus another school. I don’t know if you maybe assumed that everyone had access to the same thing. (Maddie INT 150108).</td>
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**Rubric: Lesson Enactment Exemplar Statements**

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<tr>
<th>Category Label</th>
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<tbody>
<tr>
<td>Subject</td>
<td>1</td>
<td>Answer has limited context and explicit instruction for the lesson. e.g., yes, students worked collaboratively well together, while furthering their education on asexual reproduction. Sexual reproduction was not included as previously stated in the objectives. The comparison was based on the 5 types of asexual reproduction. Originally we planned to have a PowerPoint lecture, giving information to the students on how to set up slides, but after talking to the students we realized that they were quite comfortable with the program (Daryl wiki 140208)</td>
</tr>
<tr>
<td>Ownership of the lesson (comfort level)</td>
<td>2</td>
<td>Answer has some context and some explicit instruction for the lesson. e.g., Students were through WISE projects...reading the site, checking the links...listening to wolf howling (half were engaged—may be due to their own work pace); watching videos (half); some could not locate it initially; other students helped them find the video from the link (Frank wiki 100508)</td>
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<tr>
<td>Ownership of the lesson (comfort level)</td>
<td>3</td>
<td>Answer has strong context and some explicit instruction for the lesson. e.g., Students worked in pairs to complete the activity. They were refining their scripts so there was a lot of discussion going on. The students were also doing research websites and in their textbooks to make sure that what they were saying in the podcast was accurate information. There was also discussion between groups asking for help to understand a concept or advice on how to explain it. (Merle wiki 121208)</td>
</tr>
<tr>
<td>Ownership of the lesson (comfort level)</td>
<td>1</td>
<td>Answer showed limited use of lesson design. e.g., Aspects of the work—for the most part the materials was very accessible and they researched into it—the information was good. The challenge was limiting the amount they would present. Found that the handout (commenting on handout—didn’t design)—in general the Earth's Crust needed more guidance for picking up projects; or given projects. There were too many students doing Volcanoes. Available—was broad—for the students to choose but they only seemed to choose volcano—herd mentality; and they didn't know much more. The volcanoes was the easiest to get a handle on. (Placido wiki 010609)</td>
</tr>
<tr>
<td>Ownership of the lesson (comfort level)</td>
<td>2</td>
<td>Answer showed some use of lesson design. e.g., Did you feel that your lesson helped students learn the science topic better? Explain with examples (why or why not). Yes. Interactive software allowing them to create food webs and modify them easily lots of links to credible sites for extra research (Science behind Algonquin animals, MNR, etc.) (Frank wiki 180608)</td>
</tr>
<tr>
<td>Ownership of the lesson (comfort level)</td>
<td>3</td>
<td>Answer showed strong use of lesson design and gave examples. e.g., Did you feel that your lesson helped students learn the science topic better? Explain with examples (why or why not). How did you assign groups for the collaborative work?...I think the students got a better understanding, because they were the ones engaged in the topic. They always wanted to outdo the other group, so they really made sure they were up to date with their information and wanted to have the best pictures, video and PowerPoint. I decided on who I thought would work the best together (Daryl wiki 270608)</td>
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| TPCK—explain and demonstrate technology and use of it to improve the project design | 1 | Answer showed limited understanding of technology within lesson plan. 
*e.g.*, Reminders, emails, time in class; and focused student on finishing script, forced students...discussions and student work as they were doing it helped or didn’t help the students? (Maddie wiki 210109) |
| | 2 | Answer showed explained some benefit of technology within the lesson plan. 
*I think that amount of time—to do the project—was short; and could be shorter (the project—can be assigned within the week)—they know that they have to get started on it—or putting off and putting off. We can start and finish it in a short period in time.
Wiki will help this facilitation—The students need less time for the project; How do I know that there are 5-6 projects (that students were doing in other subjects). I think that this project is in and out—done and doesn’t interfere with the student other work. A long time frame just means that there is more time to put this off. Technology does make a huge different—because you get what you can get done—using Google—can get photos, videos faster.
It is appropriate that it is done in three minutes (PlacidoWiki010609) |
| | 3 | Answer has strong connection on how technology was used in the lesson plan. 
*e.g.*, I need to explain the expectations of the podcast better initially including giving out the marking scheme at the outset. It might also be a good idea to play a podcast as an example for the students. Some of them had never heard one before so it took a few classes for them to figure out exactly what I meant by the project. (MerleWiki121208). |
| Capable of addressing the fluidity of the lesson | 1 *could be 2?* | Answer has limited understanding about the fluidity of the lesson and able to gage student work. 
*e.g.*, That’s longer term. They’d be monitoring, say, growth. And that would, of course, be against the control, they’d be doing the same thing, except for the tampered water. That would take a long period of time. It would be a great exercise. 
Is there something to be learned from that? Certainly. Is that project based learning? I think so. Could it be done at home? Absolutely. Is it good science? Yeah. It’s good science. I don’t know if we’ll get a chance to do that though in the new curriculum, or in the amended curriculum. (Bill INT 200208) |
| | 2 | Answer addressed the fluidity of the lesson and was able to gage student work. 
*e.g.*, Did one class have a better advantage over other classes in understanding the science concepts? Describe the kind of activities that you saw the students engaged in? (What was happening in this activity? How many students were engaged in this activity? The had equal time to work on the project, so no one had an advantage. The best part of this project was to see the students break off and do their own part and then come together and put it altogether. Each group designated different people to do different tasks. Activities included getting a video, pictures, intro, and understanding the idea (Daryl Wiki 062708). |
| | 3 | Answer strongly addressed the fluidity of the lesson and excellent gauge of student work. 
*e.g.*, What types of things in were you involved in doing in the class today? What types of interactions lead the students to a better understanding of science? I helped provide costumes, places to film, borrow equipment, *e.g.*, computers, and Jacob’s project. Filming—has increased profiles of the class. Mentioned (in class)—Light—reflection of light *e.g.*, students—partial liked it to do video concept...Whenever they hit a snag; I could help them with; either with creative opinion or wiring things, soldering gun, side discussions. Everyone was into the topic (even though Physics not even discussed sometimes...more team work). (Charlie wiki 290508) |
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<tr>
<td>Small Group Interactions</td>
<td>1</td>
<td>Answer didn’t address small group interactions.                                                                                                               <em>e.g.</em>, How did you assign groups for the collaborative work? This part individual—therefore N/A. Next stage, it will be by picking out of a hat. (Olga 140908).</td>
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<td>2</td>
<td>Answer addresses small group interactions in some way.                                                                                                          <em>e.g.</em>, How did you assign groups for the collaborative work? What were some of the 'tricks' or teaching strategies that you used to help move the students’ project work forward? Based on their “table” groups. They share similar interests. Having the film festival day as an absolute deadline. One-one-one chatting with them, asking them questions about the project. Videos were done in both cases. The log books helped me—I enjoyed reading it. I assumed that knowing that they had to fill in something that they should be working on something that day. (Charlie 290508)</td>
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<td>3</td>
<td>Answer strongly addressed small group interactions.                                                                                                             <em>e.g.</em>, Yes, I think there is a difference between how students learn from simply listening to a teacher talk or show demos to actually researching the topic themselves and seeing other versatile examples of the topic or other ways of the topic being presented. Also students had to be creative in this project which implies that they should know and understand the topic well in order to present it in a unique way. For example, I showed some demos in class of a physics concept, the students then saw similar demos on line, which gave them ideas about how they can present the same topic, but in their own unique way. The same problems existed that normally exist in a non-technological group work effort—some students end up doing more work than others. However, there was more collaboration since students were aware that their progress was being observed and assessed online. Making them aware that their progress was being monitored online and their assessment was based on how much work they contributed to their wiki site as well as the project itself. Also, giving them strict deadlines for various stages of the project was a priority. (Maddie wiki020309).</td>
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<tr>
<td>Object (used PBL index for coding reference)</td>
<td>1</td>
<td>Answer shows limited connection to students' prior knowledge.                                                                                                    <em>e.g.</em>, The students had zero knowledge of volcanoes prior to. The students didn't recall the material—curriculum wise. The students were starting from a blank opinion. (Placido Wiki 010109)</td>
</tr>
<tr>
<td>Teacher makes connection to student ideas during class</td>
<td>2</td>
<td>Answer shows limited connection to students’ prior knowledge                                                                                                    <em>e.g.</em>, different types of the volcanoes, the students may not know about—they may not take the time to research the difference in the tectonic plates (e.g., Pacific and Rockies). Review—possibly next class. (Alex wiki310309)</td>
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<td>3</td>
<td>Answer shows strong connection to students’ prior knowledge                                                                                                     <em>e.g.</em>, Sometimes when they were off the mark—I would give them a hint and I would give them a suggestions—the against and for arguments were the same...so I had to point out the information (i.e., scientific information-I had to remind the students &quot;that they had to come back from the other aspect&quot;. See rubric suggestions (by email sent to students). (Olga wiki100609)</td>
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<tr>
<td>Inquiry-Based project; Exposes students to relevant ideas to themselves or others</td>
<td>1</td>
<td>Answer shows limited connections to relevant life.                                                                                                                <em>e.g.</em>, Still they still have problems with relating the equations to the relevant situations...Whether it is a roller coaster; or device; all the concepts are still hard to grasp from equation to real life situation. (Maddie 210109)</td>
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| Example Statements of Evidence                                                  | 2           | Answer shows some connections to relevant life.  
  e.g., Wording in the rubric could have been more explicit—more scaffolding more to know what they needed out of the journals; How to make strong scientific arguments by looking at what the counter argument was. Now that we have finished—if they had been exposed to stage III—debate they would know more about the overall idea of the project. Their summary and their argument were similar—and some had to work. Pushed to do more. (Olga wiki 100609) |
| Building on student understanding within the class                              | 1           | Answer shows teacher limited engagement with students to build on their understanding.  
  e.g., But as I said, in this one, this one is, for all the years I’ve been introducing the topic, all they know is this chemical (Chemical) that will burn holes through your skin because they saw it in a horror film. Actually, there is nothing wrong with that either, but it’s just kind of limited. (Bill INT 200208) |
|                                                                                   | 2           | Answer shows teacher engage with students to build on their understanding.  
  e.g., students are busy here at the school, deadline of the final day—i.e., the movie review presentation day helped move the projects forward, stay on top of them; during designated classes—pushed to explain themselves. Actively make progress—with their own laptops; modification note—regarding project. Rijke—this group had project; built the instrumentation  
  echo group were not able to make echo as planned (i.e., cold), Stanley (student) is very construction (skilled) and so the process was familiar with him, connections made from orchestra and physics class (in sympathetic resonance group) because they were musicians. liked the motivation factor to incorporate their own talents (Charlie Wiki 300408) |
|                                                                                   | 3           | Answer illustrates teacher’s strong engagement with students to build on their understanding.  
  e.g., Because I asked them. I asked them how much work they’ve done. And again, two of the groups have done some work. This group has done a lot of work. I knew they had done a lot of preliminary work contacting people. They’d been working on that since the beginning. This group here had posted some information on the wiki, but when I went around and previously, again before you came, I pulled everyone’s up, and I asked them, have you done anything. Is there anything anywhere else that you just haven’t posted, and they said “no.” So I knew they hadn’t done any work. So that’s been a challenge. (Merle INT 100208) |
| Enables planned student activities (collaborations)                             | 1           | Answer shows limited teacher involvement with the student in the process of the project.  
  e.g., table group is already set up for collaborative work collaborative—work was even; however at the end the video editing was uneven work before; research, wiki site all even; but the final stages student(s) worked at home (and was more one/or two students working on editing) … all work was fair between groups (students in this school will police themselves, the ‘lazy’ group members would be easy to fix—nobody complains in the later grades. (Charlie wiki 300308). |
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<td>Answer shows some teacher involvement with the student in the process of the project.</td>
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<td><em>But basically I showed them the videos from last semester to give them a better idea of what was expected of them, because I think they were still unclear about what exactly they were making a video of. So, I told them that it was very open ended. They could do a rap, they could do a song as long as they did it so it’s more towards a lower grade. So, in other words, it’s easier to understand, they can explain it, they can have demos, they can have presentations, and then the actual videotaping itself that they should watch out for. The audio and the lighting and all that. Obviously, first things first was to have their Energy Transfer concept that they need to work on. That’s why the research was important, because I think a lot of them still had a problem with that figuring out what exactly they were doing.</em> (Maddie INT 290409)</td>
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<td>Answer shows strong teacher involvement with the students in the process of project (i.e., collaborations).</td>
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<td><em>I loved the pair and share activity where students read their podcast scripts to each other and then commented on the scripts. There were many changes that came out of that session and the podcasts certainly improved from that point. All suggestions/comments were recorded on the wiki site so that groups could go back and review them. I'm not sure if that was done, but if did give me a chance to see what the kids were suggesting.</em> (Merle Wiki 230609)</td>
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<tr>
<td>Teacher achieves the objectives for lesson plan (walking around, asks questions)</td>
<td>10</td>
<td>Answer shows limited teacher objectives followed in the lesson plan.</td>
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<td><em>e.g., I decided on who I thought would work the best together and would ask them open ended questions that they would have to answer and then add continuation questions as well, to get them to work further.</em> (Daryl Wiki 050509)</td>
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<tr>
<td>Teacher implements planned assessment</td>
<td>11</td>
<td>Answer shows limited ideas about assessment structure within the lesson plan.</td>
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<td><em>e.g., I think the project could be somewhat more substantial. I’m not saying I want to. I’m just saying it could be.</em> (Placido INT 310509)</td>
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<td>Answer addresses some of the assessment ideas within the lesson plan.</td>
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<td><em>e.g., The objectives were achieved template needs to be more detailed—rubric—needs to be on the site try to be in our expectations on line and what is not on-line (some didn’t use wiki and used the PowerPoint). PowerPoint uploaded onto the wiki site</em> (Alex Wiki 220509)</td>
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<td>3</td>
<td>Answer strongly addresses assessment ideas within the lesson plan. e.g., I would like to reinforce the criteria—At the initial introduction I developed criteria and marking scheme (at present the marking scheme has to be revamped). Friday—I need to remind them to complete—so that they are in a form that someone else can read themselves. (Merle wiki 240309)</td>
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<tr>
<td>Science concept taught (Specific lecture)</td>
<td>1</td>
<td>Answer indicates limited teacher engagement in the science explanation; mini-concept lesson e.g., Many of the students were concerned that some of the questions that they were using to guide their research for their project, and they were correct, for the most part... Some of the students were doing things that were in fact worldwide phenomenon, and then one of the questions was “give the location” (Placido INT 310508)</td>
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<td>2</td>
<td>Answer indicates the teacher engagement in science explanations—mini-concept lesson. e.g., The second cycle improved the design by following the students as the planned their video. The journal log-book was introduced—which we talked about in the first cycle design but somehow got left out. However, these projects were okay. But some problems arose. Students that saw other student projects were somehow influenced by the design. The projects became more about the story than about the physics. The videos become longer, and the students also did not show me their work during the process—so in some cases had no idea what the students were working on” (Charlie INT 29/05/08)</td>
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<td>3</td>
<td>Answer indicates strong teacher engagement in science explanations—mini-concept lessons. e.g., What were the students misconceptions coming into the lesson and how do you think you have address this? Misconceptions of coil gun—why does wire coil transfer energy versus wire across—(little thing but big idea)...Shouldn’t really work. Jacob Ladder—the students liked the spark. I was trying to move them to where the spark was gained. I was trying to understand how the box was working. Physics good that was explained. (Charlie wiki 220808)</td>
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<tr>
<td>Added to lesson plan on the ‘fly’ (deepen the PBL aspects); as well as addressing unexpected (real time)</td>
<td>1</td>
<td>Answer indicates limited ways in which teachers conversed with the students to enhance the project. e.g., I think the lesson met and surpassed my expectations. I was very impressed with what the students put together in the time frame given. They put together a very informative PowerPoint using creativity and useful knowledge. I wouldn’t change anything as the projected based lesson was excellent. (Daryl Wiki 140208)</td>
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<td>2</td>
<td>Answer indicates some ways in which teacher conversed with the students to enhance the project. e.g., The “brain storming” of ways to present their concept in a video format. This followed research, which should of enhanced their learning. Also seeing other group presentations was definitely an aid to help them understand the science concepts. (on the fly—during the class) (Maddie Wiki 010309)</td>
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<td>Answer indicates strongly the ways in which teacher conversed with the students to enhance the project. Whenever they hit a snag; I could help them with; either with creative opinion or wiring things, soldering gun, side discussions. Everyone was into the topic (even though Physics not even discussed sometimes...more team work). (Charlie Wiki 220808)</td>
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<tr>
<td>Type of Technology chosen for the lesson. (video; wiki site (student) PPT, LCD projector)</td>
<td>1</td>
<td>Answer indicates limited use of the tool within their class. e.g., Originally we planned to have a PowerPoint lecture, giving information to the students on how to set up slides. but after talking to the students we realized that they were quite comfortable with the program (Daryl Wiki 140208)</td>
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<td>Answer indicates some use of the tool within their class. At the wiki—resource time; the students were working (two would be working—but one was always lost). Class 1—role playing in the groups—separated tasks. Some groups—girl groups more likely to collaborate; versus the boys—delegated and worked on it separated. Class 2; the class—groups delegations of the roles; i.e., one person did Script; one person for demonstrations/props; making the models; filming (videography-editing). Filming was edited by the same person. (Maddie Wiki 220608)</td>
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<td>3</td>
<td>Answer indicates strong use of the tool within their class. e.g., I did like being able to see the work in progress on the wiki site. It allowed me to keep tabs on the progress of the project and to comment on things right away. One group was really not on track with the expectation of the project and I was able to give the quick and easy guidance on the wiki site. (Merle Wiki 220608)</td>
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<tr>
<td>The lesson plan used within the lesson 15</td>
<td>1</td>
<td>Answer shows that teacher referred to lesson plan a limited amount of times. (changed plan…)Well, I wanted, one, the presentation that every person in the group must speak. And that they use outside voice inside. A lot of these students mumble and they talk to the wall. They look at the power point when they are speaking. We can’t hear them. So I wanted to make sure that when they speak, they use the outside voice so the whole class can hear, and it grabs their attention as well. One of the other things I wanted them to do was that to make sure all of the students were listening, and understanding. I wanted one person per group that was sitting and watching to ask a “follow up” question regarding the topic. So the binary fission group was up at the front, the spores, budding, propagation, and fragmentation. Each group would have a follow up question to either reiterate the slides or to get further knowledge. (Daryl INT 151107)</td>
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<td>Answer shows some teacher reference to lesson plan. This time (Class 2); the students worked on the script write away -and this was important. This time the group that wrote the script they knew what they were doing; only gave a week to work on the script. This time (Class2); this year—lab work was very focused and content driven; STSE expectations.—for Pearson competition video submitted -(Class 1) ... more open ended—the students need more direction; (Maddie Wiki 220608)</td>
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<td>Answer illustrates strong teacher reference to lesson plan. e.g., How did you feel the overall lesson went? What would you change in the lesson if you had the chance to? (adding) pictures of the exhibits—video podcast—instead of audio (directing people) (Merle 220308)</td>
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<tr>
<td>Tool/Rule</td>
<td>Teacher reflects on enactment 17</td>
<td>Answer indicates limited reflection and comments about readjusting lesson. e.g., went well, would change it so there are fewer activities or more step-by-step instructions on the screen, would also like to give more time for planning their project, but our curriculum really doesn't allow that kind of freedom since we're covering 2 years’ worth of expectations into one, there needs to be some kind of hands on activity in between the different stages so students aren't stuck to the computers the whole time—their attention level could be improved (Frank 180608)</td>
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| Teacher reflects on student learning through the lesson enactment. | 1 | Answer indicates limited teacher recognition of student learning during enactment.  
  e.g., I assigned the groups based on previous information/experience I have seen in the classroom. I tried to put students together that could keep one another on track. Students that had special needs tended to be placed with students that would provide extra information (Daryl Wiki_140208) |
| Teacher reflects on student learning through the lesson enactment. | 2 | Answer indicates some teacher recognition of student learning during enactment.  
  e.g., The really good myths really seemed to take something they were always wondering about and they took the time to research. More than anything at this stage, it makes them understand the connection between chemistry and the reasons for everyday myths. Biggest misconception was that they were solving their own myths. They were overwhelmed with the amount of research they had to do initially, and I had to reassure that they were only posing the question. Despite this, some of the products contained perhaps too much chemistry which they didn't need to do. They did seem to enjoy it. (Olga Wiki 240908) |
| Teacher reflects on student learning through the lesson enactment. | 3 | Answer indicates exception teacher recognition of student learning during enactment.  
  e.g., The lesson did achieve the aspects of project-based learning probably better than a regular group project. Having access to discussions and student work definitely helped the students by letting various groups see how others were progressing and also allowing to give out and accept advice from other group members as well as the teacher was effective in stimulating progressive action on behalf of the students. (Maddie Wiki 020309) |
| Able to demonstrate after the lesson—how they would change—during the lesson (i.e., examples of change because of the reflection) metacognition | 1 | Answer contains limited evidence that enactment helped them in their lesson revision.  
  e.g., I think the overall lesson went well. The only issue was being so close to the end of the school year, students started missing classes due to conflicts. So I would do it earlier in the year. It was a 4 out of 5. (Daryl Wiki 270608) |
| Able to demonstrate after the lesson—how they would change—during the lesson (i.e., examples of change because of the reflection) metacognition | 2 | Answer contains some evidence that enactment helped them in their lesson revision.  
  e.g., time management (podcasting)—3 classes (one class working initial/brainstorming/visiting exhibits; one class—template completion; pictures of 4 exhibits; research for curriculum/ministry guidelines; writing of script (feedback online); one class—sharing on podcasting—critique in class (with template); prior to final copy) then submission of podcasting on line. (changes to project... pictures of the exhibits - video podcast—instead of audio (directing people) (Merle Wiki 210309) |
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| Teacher uses community ideas in enactment | 20 | Answer shows limited use of community advice within their delivery of the lesson.  
  e.g., N/A (Daryl INT 290508) |
| Div. of Labour & | | Answer shows some use of community advice within their delivery of the lesson.  
  e.g., Can we change this? Not “do you have any suggestions” but “include your suggestions for communication.” How about just those four? That’s fine. So I need to add that to the wiki somehow. Can we have a template for the discussion? …Yeah. I have a template for the discussion, but also I think what Merle did was just to tell them to copy it and paste it from the template section, which worked just as well. So, but I know that it was effective. Did you see Merle? Merle used the wiki site also for podcasting and she had them do the same thing you did, which is give each other feedback, and she really liked that because what happens it that was the first time that they were able to speak out loud their script? And once they were speaking out loud, they realized that they weren’t explaining it, or explaining it properly. Which may not be a bad augmented thing for yourself, in some respect. Thinking about that one? It’s kind of a cool idea. Where do you think the student will be, or are challenged in this lesson plan? Well planning the video is challenging. Certainly the editing is challenging. Then with all the computer issues. I’d like to think the commenting on others won’t be that challenging for them. It will be more like a chore that they have to do, I think. (Charlie Wiki 070509) |
| Community Influence of Community | 1 | Answer shows strong use of community advice.  
  We did take the time to go over how to navigate through and perhaps this took some class time away. This was kept to a minimum (about 30 minutes) and Cheryl (researcher) was there to help them through. In addition, I did go over a PowerPoint to describe the assignment, which took about 20 minutes. I don't see this as a problem because it integrates well to the course. There were problems of deleting because when they post and make an error they are not permitted to move or delete mistakes, so it took time to wait to ask. My expertise is still minimal and I also don't have rights, so they needed to speak directly with Cheryl (researcher). (Olga Wiki 240908) |
| | | How did the community (peers) influence their lesson plan?  
  e.g., Absolutely. In fact, that’s one of the things that I really … I really feel privileged to be able to work in this community because there is so much collaboration and interaction. (Merle INT141108) |
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<td>The community influences their lesson plan. Maybe you could use images or diagrams to illustrate what you’re rapping about” question mark. (Maddie responding to Charlie’s lesson ideas about student work)(Maddie INT 020608)</td>
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<td>3</td>
<td>The community strongly influences their lesson plan (Shawn) The videos were supposed to be like ‘shorts’ with information that I could play to younger classes. (Merle) But what does that matter? You have students expressing own understanding and that is valuable. You have so many resources of YouTube that you don’t need this assignment to do, what you could have YouTube do better. (COMM INT 020609)</td>
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**Total and Comments**