TRANSFORMING PRACTICE: DESIGNING FOR LIMINAL TRANSITIONS ALONG TRAJECTORIES OF PARTICIPATION

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DEDICATION

For Mark

because he never quit, even when enough was enough.

To my Zissou

for the hapdef and the kwajadoo.

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PREFACE

When looking from a window at beings passing by on the street below, I … say that it is men I am seeing. … [But] what do I see from the window beyond the hats and cloaks, which might cover automatic machines?
—René Descartes, 1641

She could see the image of her son, who lived on the other side of the earth, and he could see her. … "What is it, dearest boy?" … "I want you to come and see me." "But, I can see you!," she exclaimed. "What more do you want?" … "I see something like you …, but I do not see you. I hear something like you through this phone, but I do not hear you." The imponderable bloom, declared by discredited philosophy to be the actual essence of intercourse, was ignored by the machine.
—E. M. Forster, 1920

Until you are at home somewhere, you cannot be home everywhere.
—Mary Catherine Bateson, 1995

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Schooling is grounded in the notion of transfer—the idea that classroom activities serve students beyond mastering the intended curriculum—but theorizing general consequences of learning and ways curricula can support them remain open questions. Building on "situative" perspectives, this dissertation enlists video game technologies and methodologies to simultaneously design for and theorize about transitional, or liminal, forms of participation as an alternative conceptualization of the general consequences of learning. Liminal transitions are activities along the pathway through a gaming curriculum that engage learners with ways of doing science and being scientific that are different from but complementary to curricular experiences. A video game-based ecology curriculum in a multi-user virtual environment called *Quest Atlantis* served as the primary curriculum, but incorporated liminal transitions for the purposes of this dissertation. Enactments in a fourth and a sixth grade classroom were analyzed to understand ways that these embedded activities both support learning and make knowing visible. Corresponding design strategies were also examined in order to understand and refine learners' opportunities to transform scientific practices and evolve scientific roles. These interpretive analyses focused on learners' trajectories of participation with the curriculum and the transformations arranged by liminal transitions. Findings consider cases that illuminate how students leveraged liminal transitions to make meaning with and across the curriculum and other cases that explore design tensions encountered in arranging these activities. A multi-level assessment framework also generated a

quantitative profile of individual learning in terms of formal scientific concepts and learning standards. Assessment across these levels framed concepts and standards with increasingly general relation to the curriculum that provides broader perspective on learning and its general consequences. In order to better understand the impact of liminal transitions, a quasi-experimental comparison contrasted these assessment outcomes with a classroom that enacted the primary curriculum with unembedded formative assessments and feedback. Effect sizes were consistently around 0.2 larger when the curriculum was paired with liminal transitions, but differences were statistically unlikely. Conclusions discuss participation in terms of the reciprocity between game player roles and practices for productive transitions across and beyond curricula and designing for situative generalizations.

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INTRODUCTION

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> The advantage of confining attention to a definite group of abstractions, is that you confine your thoughts to clear-cut definite things, with clear-cut relations. … The disadvantage of exclusive attention to that group of abstractions, however well-founded, is that, by the nature of the case, you have abstracted from the remainder of things. In so far as the excluded things are important in your experience, your modes of thought are not fitted to deal with them (Whitehead, 1925, p. 59).

The relationship between "clear-cut definite things" and "the remainder of things" is inescapable in views of learning where context and content remain inextricably related. Scholars continue to develop relational theories of learning (Barab & Roth, 2006; Brown, Collins, & Duguid, 1989; Gibson, 1979; Greeno, 1998; Lave & Wenger, 1991) that guide the development of rich curricular experiences with science. These curricular designs aim to situate science content in contexts where it is meaningful in order to provide students with opportunities to appreciate ways in which it is useful. As a result, curricula redress an important context-content imbalance reflected in Whitehead's (1929) widely cited concerns about "inert" knowledge. Whitehead argued that backgrounding context in order to foreground content ultimately compromises an appreciation for either one. Learning is still situated, he argued (1925), but situated in the inescapable constraints of abstraction. In the context of education, these inescapable abstractions often serve as a classroom currency exchanged for grades but never used beyond schooling (Lave, 1993). In this light, the interactive, virtual environments featured in video games and game-

based pedagogies represent contexts-of-use that promises to avoid forms of learning that lead to inert knowledge. At the same time, redressing an apparent overemphasis on content runs the risk of exchanging one inert form of knowledge for another. That is, cautiously backgrounding content in order to foreground the contexts to which it relates can situate learning in the concrete particulars of an immediate situation without appreciation for its broader relevance. This dissertation explores the relationships between content and context in terms of their broader relevance and therein addresses a longstanding debate about the general consequences of learning.

While educational psychologists agree that learning has general consequences (e.g., Judd, 1908; Greeno, 1997), contentious theoretical debates underscore continuing uncertainty over the generalization of learning (Detterman & Sternberg, 1993). The idea of "transfer," for example, posits that the knowledge a student acquires in one context can be applied in another context. Some scholars suggest that the scope of transfer as it is generally discussed may actually be too general to be useful in guiding research efforts and is therefore in need of a more specific taxonomy (Barnett & Ceci, 2002). Others believe that the notion of transfer itself may be fundamentally flawed and should therefore be abandoned altogether (Beach, 1999). These viewpoints illustrate two views in a multifarious and longstanding debate about the scope and usefulness of transfer for conceptualizing the general consequences of learning more broadly. It is against the backdrop of these contending viewpoints that the research problem for this dissertation emerges.

The research problem in this dissertation is first presented in terms of a fictionalized account that features an alternative notion of transfer. This vignette depicts

an illustrative situation so as to convey a "feel" for the construct of "liminal transitions" explored in the rest of the introductory chapter. The vignette is intended to provide a concrete grounding for the theoretical discussion that follows. The passage begins with an idealized account of a fourth grade student's experiences with science and subtly transitions to a description of what general consequences of that learning may be.

> *As part of an innovative science internship program, a park ranger has asked Susan to help him solve a problem at a national park. Fish in the river are dying and the ranger is providing the full resources of the park to help solve the problem. As a first step, the ranger advises her to learn about the park. Susan hikes the park trails and the surrounding areas. She even strikes up conversations with adults she encounters. Some are loggers who work nearby; some are visitors to the park; some have lived in the area all their lives. Susan takes notes on all of their perspectives. After repeated exploration and lots of interviews, Susan seems to have a handle on things and explains to the ranger what she thinks is killing the fish. One of many influences is that logging close to the river is eroding the shoreline. Her explanation seems insightful. Although she did not talk about "the recession of surfaces by repeated localized mechanical trauma", she certainly had something to say about the relationship between loose soil and rain.*
>
> *The ranger is impressed by her keen sense of observation, but encourages Susan to meet with another adult—a lab technician who can help her analyze water samples. The technician trains Susan and awards her an official certificate upon mastering the process. Following his advice, she collects water samples at strategic points along the river and, with the help of lab equipment, generates data about water quality. The changes in quality from one water collection site to the next support some of Susan's earlier ideas but it suggests she might have been wrong about one of them. She reports her new findings to the ranger and recommends a course of action. Although she might not be a full-time, extensively-trained ecologist, her work during this internship suggests that she is really doing science and that she is acting like a scientist. For example, a friend from school had observed her working in the lab and asked what she was doing. Her response suggested that she did not view her work as simply doing an assignment for her internship but rather as figuring out how to balance an ecosystem and improve the environment.*
>
> *Susan knew she still had a lot more to do when she encountered another intern named Jesse. Jesse needed help and the ranger suggested that he see Susan. Although a bit surprised by the interruption, Susan felt honored*

that the ranger would send Jesse to her and was willing to figure out how she could help. Jesse had some old pieces of paper with notes and diagrams that a team of ecologists left behind. Susan sat down and inspected the papers. One seemed to illustrate a process that included soil and rainwater runoff and confirmed her earlier ideas about erosion. Recognizing this, she felt that she could help Jesse, but quickly realized that the diagrams he brought could also help her learn too. Susan explained to Jesse several ways in which what she saw on her hikes and heard from different people could help explain the diagrams. After explaining everything to Jesse she was eager to get back to her work and said goodbye to him. She later felt that this unexpected interlude proved that the ranger was right: she knew what she was doing. At the same time, she learned that scientists talked about the park a little bit differently, and that they saw similarities in things that seemed completely different. Erosion, for example, was not just something that loggers caused, but sometimes anglers too. The diagrams connected the park together in ways that she had not considered. She really had to have an opportunity to look at the park differently than she had in order to see what the scientists were saying.

The transfer debate alluded to above suggests two research problems related to this passage. First, assuming that Susan's internship with the park ranger represents a learning experience, then what might be the general consequences? That is, how does participation (e.g., an internship) serve a learner beyond it (e.g., advising another intern). Second, given what can be understood about the consequences of learning for Susan, how might the ranger and other organizers improve the internship? In other words, the ways that Susan subsequently engages with ecology, with internships, with watersheds, and so forth provide insights into the kinds of opportunities her activities provided. Transfer studies often pose variations on these questions, which are in many ways opposite sides of the same coin. This dissertation considers how subtle transitions such as Susan's shift from working with the Ranger and the park to working with Jesse and the diagrams inform these questions.

The particular telling of the story above suggests that Susan's "curriculum"

constantly engaged her in activities, and eventually she began practicing or "doing" science. For example, on one level, her work included activities like collecting water samples. On another, it included working with data representations of water. This particular telling of Susan's experience also suggested that doing science is a social experience in which people have different positions or roles, and that these roles evolve in relation to what is being done. In this sense, looking at data that represent water quality indicators yet "seeing" water is a way of being scientific. These two qualities—doing science and being scientific—represent the complementary features of "situative" theories of learning (Brown, Collins, & Duguid, 1989; Greeno & MMAP, 1998; Lave, 1988; Lave & Wenger, 1991; Wenger, 1998). It is with this theoretical perspective that the general consequences of learning are explored in this study.

As with any theoretical explanation of learning, understanding and supporting its general consequences presents a challenging problem for situative theories. Foremost among these reasons is that knowledge is not seen as a property of individuals but of social systems that include individuals. While it is beyond the scope of this introduction to present an in-depth theoretical perspective, the metaphor of an economy (adapted from Bereiter, 2002) illustrates this important general point. Financial value is a property of an economic system that does not reside in individuals alone or resources alone, but in the relations between them. In the same way, situative views contend that knowledge, or meaning more broadly, is a property of social systems that also does not reside in either individuals alone or the world alone. One can identify features of an economic system and features of a social system, but financial value and meaning are situated in their respective multiply-layered systems. Therefore, situative views fundamentally assume

that knowledge is inextricably bound to relations between individuals and their environments (Greeno & MMAP, 1998). This assumption seems to imply a basic contradiction about the general consequences of leaning in situative views: if knowledge is situated, then how does it transfer (Bereiter, 1997)? That is to say, if knowledge is tied down to and wrapped up in a context then how could it be useful elsewhere? There are theoretical responses to these questions and some will be explored in the following studies. The remainder of this section discusses how these responses define a challenging research problem for the field of the learning sciences (e.g., Lobato, 2006) and how this dissertation takes up this challenge.

Thus far, the research problem in this dissertation has been presented against the backdrop of various perspectives on transfer. It has been foreshadowed in the concrete terms of Susan's internship, which, in turn, has been framed from the vantage point of situativity theory. However, Susan's internship also featured a kind of transition because she moved from her role as novice to one of expert in the context of helping another intern named Jesse. This aspect of the vignette is related both to the theoretical crux of situative generalization and the research problem explored in this study: how can efforts to support being scientific, in addition to doing science, support learning and its general consequences? While situativity theories assume that learning remains inescapably embedded in contexts, they also assume that it can generalize or expand in scope as learners make transitions. Lave (1990, p. 325) suggests that "learning in practice must expand to include more than one level of learning activity at the same time that it includes more than one level of understanding of the subject to be learned in practice" (Lave, 1990, p. 325). This suggests that learners do not acquire more knowledge that can

be transferred, but that systems of knowing expand and become more productive. This expansion comes as learners transition within and across situations. Susan's understanding of the national park became more attuned to variations and constancies, for example, when Jesse's diagrams presented different representations.

At the same time, learning from a situative standpoint is not only about the expansion of systems of practice; it is also about being a scientific person in relation to the work that is done. Lave's (1990, p. 325) explanation continues, "learners who understand what they are learning in terms that increasingly approach the breadth and depth of understanding of a master practitioner are likely to understand themselves to be active agents in the appropriation of knowledge, and hence may act as active agents on their own behalf." In this sense, learning is about understanding science and one's self, each in relation to the other. For example, Susan's work with Jesse was as much about understanding herself as an increasingly competent intern as it was about explaining and understanding the national park at a new level. Lave suggests that this is as critical a transition as the work of sorting out Jesse's diagrams might be. It is such complementarity between practice and identity (Wenger, 1998) that this dissertation attempts to translate from learning theory into curricular design. Taking up these complementary aspects of learning, the specific research problem posed in this dissertation is how to leverage practice and identity in order to extend situated learning. It explores this problem by designing learning experiences that are open to the complementarity between practices for doing science and roles for being scientific using videogames, which are discussed presently.

Designing for the Research Problem

Technology-enhanced learning environments increasingly organize inquiry-oriented and problem-based curricula around reforms envisioned by a range of scholars (e.g., Lemke, 1990; Roth, 2005), research committees (e.g., National Research Council [NRC], 1996, 2000), and science education organizations (e.g., American Association for the Advancement of Science, 1993). Many of these digital environments specifically leverage technologies in the service of learning through authentic forms of science (e.g., Barab & Hay, 2001; Horwitz & Christie, 2000; Linn, Davis, & Bell, 2004; Songer, 2006). Building on these ideas, the digital technologies and design methodologies underlying popular commercial videogames offer virtual spaces that are of increasing interest to learning scientists (e.g., Gee, 2003b) and science educators (e.g., Squire, 2006; Squire & Jan, 2007). In turn, game-based pedagogies enlist these technologies and methodologies by tailoring off-the-shelf video games for curricula (e.g., Squire, 2004) or developing virtual environments that reflect these principles (e.g., Barab et al., in press). In this way, videogames represent a new form of technology-enhanced learning environments and a medium that provides opportunities to engage learners with rich experiences in which practice and identity are both relevant.

Video games can simulate dynamic interactions within complex systems of activity. Through these interactions, learners begin to identify with and make meaning of their experiences (Gee, 2003b). By frustrating some ways of doing things and facilitating others, a game attempts to position learners with respect to the "authentic" roles from which a situation is viewed and valued. The unfolding digital interactions thereby invite players to assume the role of the game avatar that they control (Gee, 2005b). These

provisions among others make video games particularly powerful virtual environments for learning. They may also be particularly productive research sites for understanding learning as well, which is a major tenet of this dissertation.

In addition to their pedagogical capacities, video games represent sophisticated digital design spaces. Researchers can author a virtual landscape through which academic content can be related in various ways to specific perceptual and narrative contexts and overarching systems of activity. Moreover, education scholars have suggested that, underlying its engaging veneer, some video game designs exemplify contemporary theories of learning, convincing many observers that such games powerfully reflect established principles for learning (Gee, 2003b). In leveraging gaming software "engines" and interactive digital media as learning contexts, video games have extended into formal education (e.g., Barab et al., in press; Chee & Hooi, 2002; Squire, 2004) much like they already have into corporations and governments (e.g., Cold Stone Creamery's "Stone City" and the USA Army's "America's Army"; Shaffer, Squire, Halverson, & Gee, 2005).

The uncommon degrees of immersion and interactivity into virtual contexts may provide powerful experiences with science. Many have observed that videogame technologies and methodologies provide new opportunities to actively engage learners with authentic situations. What is more important is that they can do so through the increasingly authentic interactions that constitute such situations. In turn, elaborate design and data collection options develop an equally powerful lens through which to examine learning through increasingly authentic interactions. This dissertation employs one such

gaming environment to arrange a kind of internship as well as transitions to different practices and roles in science.

Overview of the Study

The purpose of this dissertation is to use videogame technologies and methodologies to explore the general consequences of learning from a situative theoretical perspective (Brown, Collins, & Duguid, 1989). It considers how transitions from central curricular activities to peripheral but complementary activities support the general consequences of learning. By designing these transitional activities in relation to the paired notions of practice and identity (Wenger, 1998), it translates situative theory into practice in order to promote theoretical understanding of learning and refine design based research principles.

The transitions between curricular activities are considered here in two successive studies. Both use a videogame-based elementary school science curriculum developed by a team of designers that included the author (Barab, Sadler, Heislet, Hickey, & Zuiker, 2007; Barab et al., in press). The curriculum features an ecology problem in a virtual national park and two series of transitions. Meanwhile, the park itself is embedded in the broader context of a 3D multi-user virtual environment known as *Quest Atlantis* (QA, www.questatlantis.org). QA provides an internet-based virtual space where students can learn and play through entertaining and educational virtual experiences (Missions) that afford various scenarios and, with the introduction of this curriculum (hereafter QA ecology curriculum, or Taiga), introduces the first game-based science unit to users.

Through ongoing collaborations with a local school system, two teachers adopted the QA ecology curriculum, Taiga, in their classrooms for the third consecutive year.

Both teachers work in schools that serve primarily suburban communities in the same Midwestern town. In the first implementation, a fourth grade teacher and her classroom of high-performing students enacted the curriculum across fourteen class periods. In addition to completing the primary missions provided by the curriculum, students also engaged two transitional activities through which they continued in their game-based roles as "field investigators" in the curriculum's virtual "Taiga National Park." Subsequently, a sixth grade science teacher and two classrooms of mixed-performing students enacted the curriculum across fourteen class periods. While both classes completed the primary missions, one of these sixth grade classes completed the transitional activities, much like the fourth grade students in the first implementation, while the other class completed informal paper-and-pencil formative assessment activities.

In order to understand student engagement with the primary curricular missions and transitional activities, all class periods were audio- and video-recorded; student's hand-written notes and a range of electronic entries within the game (e.g., chat, emails, and essays) were compiled, coded, and categorized; and multiple students were interviewed at theoretically key moments. The study also examined students' typed responses to formal curricular tasks, to various short-answer questions embedded in the curricular activities, and to two additional essays associated with the transitional activities. The researcher developed an interpretive analysis by organizing these data along three timescales of student participation (Lemke, 2000). Through multiple cycles of analysis, the researcher developed an elaborate chronology of student activities and

artifacts and from it built case studies of student participation that highlight opportunities to do science and be scientific.

In order to understand class-wide performance, all three classes also completed pre-post assessments designed to discretely quantify individual performance via a range of questions that recontextualized both the targeted curricular content (e.g., the concept of erosion) and targeted science education standards (e.g., principles for evaluating scientific evidence) to illuminate the general consequences of learning in each condition. These assessments are characterized in terms of their multi-leveled and multi-faceted nature (Hickey & Zuiker, 2003; Hickey, Zuiker, Taasoobshirazi, Schafer, & Michael, 2006).

Research Questions

RQ1. How can transitional experiences within and across a digital game-based curriculum and different but complementary situations to which the curricular experience might extend reveal knowing and support learning?

RQ2. What principled design strategies might guide the development of game-based transitions complementary to game-based pedagogies? Specifically, how might transitional experiences both support ongoing trajectories of participation and reveal discrete moments of knowing about domain practices?

RQ3. How do such transitional experiences compare to traditional forms of formative assessment in supporting and revealing the general consequences of learning (e.g., transfer and alternative views of transfer)?

Significance of the Research

This dissertation represents an important first study of designing for liminal, game-based participation. It considers ways in which the complementarity between practice and identity can be enlisted to productively support learning transitions within and across situations. Using a case study approach, it develops deeper understanding of how this complementarity supports the general consequences of learning in terms of Beach's (1999) notion of mediational transitions. Analyses enlist a timescales approach to the organization of events in order to examine participation at three different levels of recurring activity. Results highlight rich episodes that illuminate possibilities for future research and challenges in leveraging learner roles along relatively short timescales of game play. Methodological and design implications of leveraging learner roles as a scaffold along trajectories of participation are considered.

Overview of Dissertation

In this chapter it was suggested that game-based technologies and methodologies represent a powerful new approach to pedagogy that may support learning and its general consequences. The second chapter details one possible theoretical framework for examining the enactment of game-based curriculum then reviews perspectives on the empirical notion of transfer and innovative perspectives on assessment for learning and of knowing. Chapter Two ends with a discussion of research underlying three design strategies that inform the development of the innovations considered in the 4th and 6th grade implementations that comprise this dissertation.

The third chapter explicates a theory and praxis of methodic analysis for generating data and making meaning in and across the three aforementioned classroom

enactments of the game-based curriculum. Chapter four develops an interpretive understanding of learners' trajectories of participation and the role of transitional experiences for supporting learning. Chapter five examines the design of liminal transitions in terms of the twin constructs of polycontextuality and prolepsis. Chapter six then considers pre-post assessment data that is nested within the broader qualitative analyses. It also discusses a quasi-experimental comparison of liminal and more conventional formative assessment transitions. Finally, Chapter seven concludes with discussion of findings and general implications related to theory and practice.

Definitions of Key Terms

Avatar. These are the representation of individuals in the 3-dimensional space that makes up the virtual environment. Individual's play videogames by moving their avatar through that space and interacting with other avatars.

Non-Player Character. The representations of Avatars in videogame environments can be controlled directly by players or indirectly through designed rule sets. Non-player characters are the latter set of avatars operating in virtual environments.

Trajectory of Participation. When learning is viewed as an ongoing process, then learners can be considered in terms of the past, present, and possible futures that shape and are shaped by engagement with systems of activity. A trajectory of participation represents this movement with experiences that precede, accompany, and follow the specific instances of engagement with these systems.

Transfer of Learning. When the application of skills and knowledge that an individual learns in one setting (the "learning context") learned in one context are later used in another context (the "transfer context").

Game-based curriculum. Game-based curricula use videogame technologies (i.e., navigating an avatar through 3-dimensional immersive environments and methodologies (e.g., unfolding interactions with non-player characters via elaborate rule sets) together with other classroom-based based activities (e.g., discussions, assignments, etc.) to engineer new forms of teaching and learning that feature complex forms of interactivity.

Liminality. Liminality is an anthropological concept defined by Victor Turner (1967, 1969, 1982). It refers to transitional forms of participation that specifically occur in-between the recognized boundaries of normally occurring social organization. These transitions may provide productive opportunities for reflecting on prior experience.

Liminal Transitions. Liminal transitions are a category of transitional activity that is designed to engage learners with different but complementary forms of participation during game-based curricular experiences.

Polycontextuality. This notion refers to similarities shared between different contexts. Examples of these similarities are complementarity across contexts, overlapping practices across activities, and/or invariant properties across systems. These commonalities and interconnections are embedded differently in different contexts, activities, and systems but they make use of similar tools and patterns.

Prolepsis. The notion of prolepsis refers to communication that implicitly represents something as existing before it actually does, or being known before it actually is. For example, a speaker can deliberately presume that a listener knows what will only later be revealed or discovered. This form of communication often challenges a listener to construct the speaker's assumptions in light of known circumstances. In this study,

prolepsis occurs in videogame interactions (e.g., conversation, video game play) in which meaning is presumed by the designed of a situation rather than a speaker.

CHAPTER 2

LITERATURE REVIEW

Research in the learning sciences builds on psychological, philosophical, linguistic, and anthropological traditions in order to develop design principles for constructing learning environments and to evolve theory about the learning ecologies that these designs serve. This chapter describes research themes in and across these disciplines in order to detail theoretical foundations as well as specific lines of educational research that inform the broader dissertation study. Specifically, it overviews a situative view of learning and its implications for understanding the empirical notion of learning transfer. Building on these perspectives, the chapter considers the notion of liminality and "liminal transitions" as an ontological innovation (diSessa & Cobb, 2004) for supporting learning and understanding its general consequences. Corresponding design principles for "liminal transition" are discussed. Finally, the chapter concludes by considering liminal transitions as a viable form of assessment for learning.

Theoretical Perspectives on Learning

Learning is the central aim of education. Developmental psychologist Robbie Case (1996) suggested that this means "tak[ing] the knowledge that has been acquired by one generation and creat[ing] conditions such that this knowledge can be reacquired and extended by the next" (p. 75). However, beyond this basic focus, different theoretical perspectives reflect continuing debate about relationships between human beings and their material and informational environments.

The perspective through which this study examines classroom learning assumes a direct and inextricable relationship between humans and their environments. This means that learning cannot be understood in terms of individuals alone, but rather in terms of the systems of activity or nested tools and resources in which one or more individuals participate (Greeno & MMAP, 1998). Consider, for example, a blind person walking with a cane (adapted from Bateson, 1979). Where does the individual "end" in this example: at his finger tips, at the end of the cane tapping the ground, at the floors, walls, streets, and curbs that the cane contacts? The cane and the person in Bateson's thought experiment are paired in the activity of walking such that the individual and the environment remain inextricably bound. Theories of learning emphasize the role of the individual and of the environment differently (e.g., Case, 1996; Greeno, Collins, & Resnick, 1996); however, in this study the emphasis is specifically on the ongoing relations (e.g., blind person-cane-ground) defined by some systematic form of action (e.g., walking).

Learning and Knowing as Ongoing Relations of a System

Cognitive theories of learning (e.g., Anderson, Reder, & Simon, 1996, 1997; Vera & Simon, 1993) assume stable and objective disciplinary content available for learners to discover or construct across various contexts. Reflecting western philosophical traditions (e.g., Descartes, 1641/1996), such views assume degrees of inherent constancy about knowledge and stable, if not inherent, boundaries for the contexts to which such knowledge applies. This constancy across time and space suggests that knowledge is discrete and independent of and divisible from context. In contrast, relational theoretical perspectives on learning exchange these assumptions about the stability and constancy of

an outside world for a dynamic and perspectival view of ongoing relations with that world. Lave (1993, p. 12) characterizes these different assumptions as follows:

> The difference may be at heart a very deep epistemological one, between a view of knowledge as a collection of real entities, located in heads, and of learning as a process of internalizing them, versus a view of knowing and learning as engagement in changing processes of human activity. In the latter case 'knowledge' becomes a complex and problematic concept, whereas in the former it is 'learning' that is problematic.

This contrast highlights important challenges for both perspectives. In particular, viewing learning and knowing as the ongoing processes of a system or "the changing processes of human activity" is challenging. This is because meaning is flexibly and contingently made and knowledge is constantly de-stabilized and re-stabilized with respect to the particular situation or system. A variety of related but distinct relational perspectives extend from a focus on the dynamics of learning and knowing based on the pioneering work of the Soviet psychologist, Lev Vygotsky (e.g., 1978).

Vygotsky (1978) considered these ongoing relations in terms of inter-and intra-psychological phenomena occurring initially and primarily between individuals, and only later within individuals, per se. A variety of subsequent theoretical developments also concentrate on the relationships between individuals with bodies and minds, and the material and informational environments through which they act (Barab et al., 1999; Brown, Collins, & Duguid, 1989; Engeström & Cole, 1997; Gee, 1992; Greeno & MMAP, 1998; Lave & Wenger, 1991; Pea, 1993; Rogoff, 1998; Suchman, 1987; Wertsch, 1998). Minimally, an environment includes the material environment and our bodies, but more typically includes the range of tools (e.g., forges, Spanish language) and physical and cultural artifacts that they imbue with meaning (e.g., prison bars and poems). The focus across these relational perspectives is neither the environment nor the

individual alone, but conceptualizing the ways that they reciprocally co-constitute systems of meaningful activity. In this sense, learning is a process of "tuning in" to and creating particular systems of ongoing activity. These systems emerge through transactions that constitute and negotiate relations between humans and the environments they inhabit.

It follows from the idea that learning is dynamic and relational that the idea of "knowledge" is also more aptly characterized as a continuous process of "knowing" about a goal-oriented system of activities (Greeno & MMAP, 1998). Knowing is an ongoing adaptation or transformation of these relations to meet the emergent goals of a situation. These contingent foundations suggest that knowing is a practice of making meaning with situations. Activity is therefore not simply predetermined. Rather, the material and social resources that have co-evolved as tools for meaning-making practices begin to arrange the (re)construction of meaning. However, while these tools and practices partially organize or structure activities with meanings, knowing always remains contingent. In this sense, "structure is more a variable outcome of action than its invariant precondition" (Hanks, 1991, p. 17). In sum, the ongoing relations of individual-environment systems of activity suggest that learning and knowing is an ongoing achievement of meaning-making in and across situations.

Situated Cognition

The relational views outlined above generally include a broad family of situative theories of learning (Brown et al., 1989; Greeno & MMAP, 1998; Lave, 1988; Lave & Wenger, 1991; Wenger 1998) and provide the foundation for a specific theoretical framework for understanding relations between individuals and, for the purposes of this

study, a system comprised of classroom curricular and assessment activities organized by an educational video game.

There are many ways to characterize the situatedness of learning and knowing, and the following characterization is just one version. Any environment is populated with *affordances*, or the perceived possibilities of its objects and features (Greeno, 1994). Two affordances of a wooden pencil, for example, are marking surfaces with graphite and fueling a fire. In turn, an individual's capacity to act in ways that make use of a particular affordance can be characterized as an *effectivity* (Gibson, 1979). In the case of a pencil, a camper in need of kindling and a student in need of a stylus both leverage the affordances of a pencil to achieve their specific goals. Therefore, individual-environment transactions represent the realized possibilities—the affordance-effectivity pairs and networks—that exist as relations between individuals and environments (Barab et al., 1999). In terms of schooling then, students must come to appreciate the affordances of any classroom learning environment—a curricular textbook, a formal assessment, a discussion with peers, and so forth—and leverage these affordances in order to effect a certain type of (inter)action (i.e., effectivity).

Illustrating the inextricable relations between individuals and environments in terms of affordance-effectivity pairs is a fundamental characterization of situated cognition. However, these relations are often challenging to understand and define because they can be embedded in multiply-layered systems of activity. As a simple example, a person sawing wood may also be building a house, highlighting that affordance-effectivity pairs therefore can be embedded differently (e.g., the pencil example above) and in multiple ways (e.g., the sawing example) (Lave & Wenger, 1991;

Wenger, 1998). However, the protean nature of a situation often means that activities only reveal ambiguous relations to the system or systems of activity to which they relate. Learning therefore can be framed as a learner's ongoing relations to her material and informational environment, not only because systems are dynamic but also because they are overlapping. That activity is situated across multiple layers of meaning-making highlights the value of appreciating situativity in terms of the context in which activity occurs and also in terms of the time spans across which it emerges (Lemke, 2000). In this latter sense, the idea of situated cognition considers relations across time and has suggested the idea of a trajectory.

Trajectories of Participation

The notion of situated cognition implicates a learner's being always enmeshed in some ongoing system of activity as part of the process of learning. In this sense, an activity is a present moment negotiation of a historical production (Lave & Wenger, 1991, p. 51). Learning is a transformation for the present that connects to the past and the future (Wenger, 1998) and this embeddedness along a trajectory across time highlights an affordance network (Barab & Roth, 2006).

One common lens for considering learning trajectories is in terms of an individual's participation in goal-directed activities of a broader community (Lave & Wenger, 1991; Wenger, 1998). Through participation in meaningful community activities, individuals encounter "a nexus of relations otherwise not perceived as connected" (Lave & Wenger, 1991, p. 36) and increasingly engage in a range of practices and "identities" that enable them to more fully participate in the shared goals of the community.

People define not only what they do but also who they themselves situationally are in terms of the what, where, when, and how that precede and may possibly follow or, more broadly, in terms of ongoing participation. The idea that participation addresses not only the ways individuals engage in activities but also the ways they identify with activity underscores a key aspect of several views of situated cognition—participation reflects practices and identities (Packer & Goicoechea, 2000; Wenger, 1998). Participating in a science curriculum is therefore about both doing science and being scientific. Thus, situationally-defined identities are a negotiated experience between individuals and the physical and social environments that they engage. This negotiation is in terms of the local and immediate (e.g., a laborer sawing wood) but may also relate to broader constellations of identification (e.g., an architect or carpenter building a house). That doing science and becoming scientific are ongoing processes of negotiation underscore the value of viewing participation in terms of a trajectory. A trajectory reflects relations not in any fixed sense, but rather as an ongoing movement with "a momentum of its own in addition to a field of influences" (Wenger, 1998, p. 154). In this way, the meaning of practice and identity remain embedded along these trajectories. To be clear, it is not that meaning is represented apart from the world, but rather that meaning is constituted through ongoing participation with the world. Therefore, representations are meaningless apart from their embeddedness along trajectories of participation.

Viewing activity in terms of a trajectory of participation with relation to the past and future begins to reveal the overlapping systems to which learning and knowing relate, such as in the case of sawing above. In this sense, activities reveal ongoing participation in immediate experiences with the material and informational environment, but they also

reveal understandings of the past and future that shape and are being shaped by these immediate relations (Lave & Wenger, 1991). Considering situated cognition in terms of trajectories of participation therefore begins to illuminate learning both in terms of the immediate experience (e.g., sawing wood) and its longer term influences (e.g., architecture and carpentry).

In sum, the theoretical perspective outlined in this section assumes that learning is an ongoing process of attuning to the flexible and contingent relations between individuals and their environments; that learning is situated in the affordance-effectivity pairs of immediate experiences; and that learning is simultaneously situated along real time-historical trajectories of participation that include negotiated understandings of and identification with a past and future.

While these assumptions define one among many perspectives on learning and knowing, they have powerful implications for both supporting and understanding classroom learning (Brown et al., 1989; CTGV, 1993). Videogame technologies and methodologies already employ many of these insights in the design of rich virtual environments and sophisticated player interactions (Gee, 2003a). Educational researchers, in turn, are beginning to leverage many of these design principles in order to develop learning trajectories that resemble the authentic situations through which scientific understandings initially emerged (Barab, et al., 2007; Barab et al., in press). As technology-enhanced curricular designs afford increasingly situated classroom-based opportunities to learn through authentic, albeit virtual, participation, there are corresponding opportunities to leverage these experiences in the service of a broader sense of situativity, which is discussed further in the next section.

Situated Learning, Transfer, and Beyond

Despite influential characterizations to the contrary (e.g., Anderson et al., 1996), situativity theorists are deeply concerned with understanding and fostering ways of learning that have general consequences (Greeno, 1997). However, situative perspectives on the idea of generalization (e.g., Beach, 1999; Hatano & Greeno, 1999; Lave, 1988) contrast with views grounded in more cognitively oriented notions of transfer (e.g., Barnett & Ceci, 2002). The conceptual notion of transfer as the transportation of knowledge from one setting to another overlooks the relational work necessary to make that knowledge relevant across settings and the material and informational affordances that enable this work in the first place.

Situative views on the empirical notion of transfer do not attempt to resolve these relational issues so much as to "dissolve" them in the broader notion of generalization. Beach (1999, p. 112) characterizes generalization as "the continuity and transformation of knowledge, skill, and identity across various forms of social organization." Insofar as generalization involves multiply-layered relations, the conceptual notion of transfer and transportable knowledge represent epiphenomena afforded by uncommon degrees of continuity across settings. The singular representational procedure associated with transfer is, in this view, relatively limited and precludes an understanding of the transformations underlying transitions.

Situative alternatives to the conceptualization of transfer assume that the ongoing transactions of meaning between people and their material and informational environments inevitably maintain or transform what knowing means. In this view, people alone cannot simply transfer learning because knowledge is a property of the ongoing

transactions and not the individual. In connection to relational views of learning and situated cognition, persons and their physical and social environments remain inseparable, and the ever-changing processes that constitute learning and knowing in human activity remain embedded in these dialectical relations (Cole, 1996; Lave, 1993). McDermott (1996, p. 277) suggests that "it probably makes more sense to talk about how learning acquires people than it makes sense to talk about how people acquire learning"; and by extension, it probably makes more sense to talk about how knowledge is attributable to situations more than it makes sense to talk about how situations are attributable to knowledge (cf. Hatano & Greeno, 1999). Situative views assume that knowledge is always attributable to the situations through which individuals and environments transact meaning.

The idea of generality in these views is understood in terms of the transitions across contexts that learners navigate in order to pursue broader, but still situationally-defined goals. Two specific situative alternatives to transfer have been characterized in terms of productivity (Hatano & Greeno, 1999) and consequential transitions (Beach, 1999). Particularly relevant to this dissertation is Beach's (1999) theorizing of "mediational" consequential transitions that simulate or project participation with activities not yet (fully) experienced. Mediational transitions occur along a continuum from classroom simulations of a world beyond school to some form of incomplete access (i.e., partial or peripheral) to authentic real world participation, but the continuum itself lies between actual-current and possible-future participation. Therefore, mediational transitions represent a kind of intermediate and mediating situation along a trajectory of participation, somewhere between the constraints that real time participation imposes and

the affordances that probable pathways of participation enable. Gaming activities that arrange mediational transitions may provide powerful opportunities for learning while also revealing the empirical notion of transfer in ways that are conceptually congruent with situated cognition.

Designing Liminal Transitions in a Game-Based Curriculum

Building on these situative assumptions about learning and transfer, this section details lines of research that inform the transitional designs developed for this dissertation. It addresses three complementary notions that aim to support and understand the general consequences of learning as conceived by situative theories and, in particular, Beach's (1999) idea of mediational transitions. These three notions are liminality, polycontextuality, and prolepsis.

Liminality

The theoretical notion of mediational transitions (Beach, 1999) is reflected in the anthropological studies of Victor Turner (1967, 1969, 1982), who proposed a category of transitional cultural phenomena that operate in-between the normally recurring patterns of different kinds of social organization. Turner labeled this class of events liminality and describes them in the following excerpt.

> [W]hen persons, groups, sets of ideas, etc, move from one level or style of organization or regulation of the interdependence of their parts or elements to another level, there has to be an interfacial region or […] an interval, however brief, of *margin* or *limen*, when the past is momentarily negated, suspended, or abrogated, and the future has not yet begun (Turner, 1982, p. 23)

These intervening episodes in-between, however short or long, characterize a transition between preceding experiences and unrealized future possibilities. As an attribute to the social world, liminality represents a kind of "ontological innovation" that seeks to explain

the order or structure of participation in complex cultural settings (diSessa & Cobb, 2004).

While developed and studied in anthropology, liminality may serve as an inspiring construct for education and video game-based pedagogy in particular. This section considers liminality as a useful strategy for arranging mediational transitions and for generating and selecting design strategies along a pathway of game-based learning. Before doing so however, an important caveat associated with liminality is that its initial conceptualization derived primarily from initiation rites in West Africa (e.g., Turner, 1967). These early studies deliberately targeted small-scale communities with stable and cyclical cultural structures where biological and meteorological rhythms drove change. These well-defined community conditions, Turner assumed, maximally expressed liminality. At the same time, these conditions do not necessarily reflect the relatively dynamic communities that students belong to. Nonetheless, liminality reflects a broader phenomenon in which prior experiences with a culture or socially organized system of activity are engaged differently.

Turner (1967, 1969) suggests two basic features of liminality – simple social structures and complex cultural forms. Liminal activities eliminate the everyday structures that preceded them (e.g., status in social relationships) without taking up the possible social structures to follow. In this sense, liminality destructures the past without prestructuring the future. Meanwhile, liminal activity also imbues these simple social structures with an array of symbols that relate to complex cultural factors. As "evocative instruments", Turner (1967, p. 108) argued that these symbols foster reflection about the culture and an individual's role therein:

> The communication of [cultural symbols] both teaches the neophytes how to think with some degree of abstraction about their cultural milieu and gives them ultimate standards of reference. At the same time, it is believed to change their nature, transform them from one kind of human being into another.

The complexity of cultural symbols reifies perspective and transforms individuals, providing new perspective on themselves and their culture. Together, the complexity of cultural symbols and the changes in social status emphasize transformations that reflect Beach's (1999, p. 112) definition of generalization—"the continuity and transformation of knowledge, skill, and identity across various forms of social organization." Cultural symbols as "evocative instruments" serve to transform knowledge and, coupled with simplified social status, further aim to transform identity in the traditional forms of liminality that Turner's (1967) excerpt considers.

At the same time, Turner also emphasized the complementarity of both simple social structures and complex cultural symbols with the broader interactional interplay underlying them. He argued that liminal experiences represented more than simply another form of cultural activity but activities critically important to both the order and pattern of those cultures. In this regard, Turner (1969, p. 42) characterizes liminality as a

> loosening of connections between elements customarily bound together in certain combinations [in which] novices [are] induced to think, and think hard, about cultural experiences they had hitherto taken for granted. The novices are taught that they did not know what they thought they knew. Beneath the surface structure of custom was a deep structure, whose rules they had to learn, through paradox and shock.

Liminality situates individuals in new and unfamiliar circumstances with ambiguous intermediacy between past and future experiences. While these situations are new, individuals remain embedded in the broader social systems that precede and follow these activities. However, the paradox and shock of unfamiliar circumstances and complex

cultural forms, Turner suggests, reveals an underlying structure. These disconnects disrupt "what they thought they knew" about the patterns of participation arranged by normal community functioning and, in Turner's view, provoke adolescent initiates to reconsider their experiences in the community. Liminality therefore concretizes the idea of an intermediate and mediating space that underlies Beach's (1999) notion of mediational transitions. That is, liminality suggests an experience or activity in-between a trajectory of participation, interleaving a learner's present moment and possible future developments along this trajectory.

As a conceptual framework, liminality has already guided research in naturalistic settings and for instructional design. In naturalistic inquiries into liminality in business organizations, Tempest and Starkey (2004) developed a case study of "liminal communities" emerging in the UK television industry and their effects on individual and organizational learning. Their study details the structural tensions of temporary project groups, describing positive impacts such as a broader scope of learning opportunities and negative impacts like lesser access to organizational training. Similarly, Sturdy, Schwarz, and Spicer (2006) conducted an ethnographic study of business dinners as sites for liminal activity. Their analysis suggests levels and degrees of liminality organized by the particulars of the venue, agenda, and attendees. Moreover, they underscore that liminal activities are a social achievement accomplished by monitoring and maintaining not-too-business-like conversations. While these two studies and others like them (e.g., Garsten, 1999) provide naturalistic accounts of liminality, their conclusions provide only very general principals related to the simple and indeterminate structure of the groups they considered.

Liminality has also been considered in terms of a domain-specific theory of learning and instruction. Meyer and Land (2003, 2005) detailed a constructivist theoretical perspective on the liminality of conceptual understanding. In their view, a given discipline includes "threshold concepts" that can induce a period of liminality in disciplinary understanding that ultimately changes, either partially or wholly, the learner's perception of the discipline. These liminal periods are both difficult and transformative because threshold concepts reveal a hidden interrelatedness within a discipline. In this way, Meyer and Land theorize that the conceptual complexity of key disciplinary ideas, much like the cultural complexity of symbols that Turner observed, can arrange liminal experiences and, when grasped, transform a learner's understanding. Like the studies in business organization above, the idea of threshold concepts takes up the indeterminacy of liminal experiences, but exchanges the ambiguity of social structure for that of disciplinary structure. As these studies all suggest, the general idea of liminality can be used to organize interpretations of important phenomena. Moreover, liminality provides a productive and potentially powerful conceptual framework for understanding activity and supporting learning.

Building on Turner's ontological innovation, this dissertation employs the notion of liminality as a plausible framework for designing liminal transitions along the pathways arranged through game-based pedagogies to support trajectories of participation. Specifically, by simplifying social structures and complexifying cultural symbols, liminal design strategies may engage students with a kind of "paradox and shock" that engages learners with underlying cultural structures. The design strategies for supporting learning and understanding knowing that liminality suggests are discussed in

terms of "polycontextuality" and "prolepsis" in the next two sections. Meanwhile, the specific design implications for the game-based curriculum featured in this dissertation appear in the curricular description in the next chapter.

Polycontextuality

The idea that the meanings of scientific principles, among other forms of knowing about the world, remain embedded in and across different contexts is a central feature of situativity theories. Yrjö Engeström (1987; Y. Engeström, R. Engeström, & Karkkainen, 1995) suggests that traversing different situations can expand knowing by recasting learning as the appreciation of invariant properties shared across different contexts. Engeström thus coined the term *polycontextuality* to reflect an appreciation of the interconnections across situations, or more specifically, the various contexts with overlapping or complementary practices, tools, or goals that share similar constraints and affordances. Polycontextuality, therefore, reflects the idea of mediational transitions and liminality alike because each new context that a learner encounters represents the progressive recontextualization of activity across multiply-layered contexts.

Prior studies suggest that designing for polycontextuality may be a useful notion for supporting learning beyond the immediacies and particulars of any one situation. By designing activities that highlight the complementarity of different situations, learners may engage in dialectics that involve thinking "both beyond and about an immediate situation in more general terms" (Lave, 1993, p. 13) and involve transforming practices in terms of the polycontextual qualities that such complementarity suggests. Gutiérrez, Baquedano-Lopez, & Tejeda (1999) considered ways in which overlapping practices across the various languages spoken at home and languages of the classroom converged

in a school curricular unit. Their analyses suggest that the unit supported productive hybrid language practices that intersected multiple, complementary practices of home languages, underscoring Yrjö Engeström's (1987; Y. Engeström et al., 1995) argument for expanding knowing through polycontextuality. In another study, Leander (2002) suggests that the complementarity of two literature projects supported contextual interconnections that, in turn, productively transformed both learners' identities and practices. These studies suggest that engaging complementary practices and situations engage learners in a process of reifying multiple contexts learners appreciate underlying consistencies as polyconextual relations across multiple settings and, reciprocally, concrete settings in terms of invariant, polycontextual features.

With regard to liminality, polycontextuality reflects the use of complex cultural symbols as evocative instruments and suggest that liminal transitions can re-arrange students' trajectories of participation in terms of the complementarity between immediate curricular contexts and intermediate, transitional contexts. These transitions negotiate meaning across different but complementary gaming situations and can foster appreciation for underlying polycontextual consistencies along Beach's (1999) continuum from simulated to peripheral participation. These features of liminal transitions, in particular, arrange useful activities for revealing knowing and supporting learning. At the same time, the fact that learning and knowing also depend on the ways that complementary contexts are embedded in experiences suggests that simply dropping students into a new context is problematic and uncommon (Lave, 1993). By arranging opportunities to engage contexts that are framed in relation to a learner's prior experience or preceding participation, the design of liminal transitions can arrange for

polycontextuality without disrupting a believable pathway through a game-based curriculum. However, just as arranging for complementary contexts requires consideration of contrasting prior contexts, it also requires an appreciation of the roles through which a learner identified with these prior contexts.

Game-based strategies for liminal transitions simultaneously consider the productive discontinuities across contexts and the potential affordances of maintaining consistent learner roles across these changing contexts. That a trajectory of participation is viewed in terms of doing and being suggests that a design strategy can maintain the trajectory of being scientific while potentially reframing the trajectory of doing science. Further, because assessment situations are not themselves curricula, this disruption must be a relatively bounded and brief activity in comparison to the curriculum.

Prolepsis

Liminality suggests that individuals encounter some form of "paradox and shock" that recasts prior understanding in new terms and that these encounters occur in simplified social situations. In the context of transitions that support learning and reveal knowing, this section considers prolepsis as a design strategy for inducing a corresponding state of surprise and contradiction.

Prolepsis refers to social interactions in which a speaker presumes that a listener can understand an apparently ambiguous utterance through contextual cues that accompany or follow after that utterance. Stone (1993) provides an example in the context of a museum patron's question to a guard.

Patron:	Where is the impressionist collection?
Guard:	It is down the hall just after the kitchenware.
Patron:	I beg your pardon?
Guard:	Just beyond the oriental pottery.

The guard clearly responds to the patron's question but in using the word "kitchenware" references an out-of-place description of oriental pottery. Prolepsis creates a paradoxical interpretive interchange because what is said only partially reveals what is made known. The guard says "kitchenware" as a light-hearted joke that is only clear with contextual cues—possibly after the patron sees the pottery and probably after the guard's next comment. The intervening moments can sometimes be quite complex because the proleptic statement serves to induce presuppositions about the speaker that, in turn, positions the reader to expect to understand—a kind of trigger for "anticipatory comprehension" (Rommetveit, 1974, p. 88).

Prolepsis is not only a linguistic move for triggering presupposition, but a non-verbal one as well (Rogoff, 1990; Wertsch, McNamee, McLane, & Budwig, 1980). This study considered game-based curricular activities that design for prolepsis using language and other contextual cues. Pervasive background conditions can serve as cues in virtual environments and can be embedded in an unfolding curriculum in order to support trajectories of participation. The proleptic withholdings present challenges. These challenges can engage individuals in the work of determining the underlying relevance of withheld or seemingly unrelated information, engaging readers and games players alike in the work of understanding what was entailed or taken-for-granted in a new utterance or activity.

An integrative framework that considers proleptic scaffolding as the work not only of language but participation more broadly, including practices and roles, is not only possible but also one that interactive digital media can arrange powerfully. Players and games construct a shared situation defined in terms of the past, present, and anticipated

future interactions between them. These patterned interactions, in turn, support and constrain the range of (re)actions (Stone, 1993). Prolepsis may provide a strategy for supporting participation with these situations in terms of the ways of being that games afford much like Rommetveit (1979) describes its role in language and literature.

> [A]ssumed shared presuppositions may. . . also be conducive to intimacy and even lead to an expansion of the dialogically established here-and-now. Such a process of prolepsis … is often encountered in fiction when the reader feels (correct1y) that he has comprehended something in addition to what he actually has read. What from a strictly "objective" or "public" point of view appear as unwarranted presuppositions on the part of the creative writer may then more appropriately be conceived of as self-fulfilling assumptions by which the reader is made an insider of a tacitly expanded and enriched here-and-now. He is made an insider—not merely informed about it—precisely because that expanded social reality is taken for granted rather than explicitly spelled out. (p. 167)

Game players ideally "project" themselves into the roles of the avatars they control (Gee, 2003a; 2005b). A proleptic design strategy may, in turn, project players into liminal transitions by making them insiders to an expanded social reality about their participation and the situation with which they are engaging. In this sense, game-based pedagogy can design for trajectories of participation in terms of the roles that games invite players to inhabit; and prolepsis, in turn, may provide one strategy for leveraging these trajectories of participation in order to arrange and support liminal transitions.

Proleptic events design productive mediational transitions through new and unfamiliar situations. As a design strategy, prolepsis arranges liminal transitions by fostering circumstances that produce what Turner (1969) described as "paradox and shock." Liminal transitions in education (as transitions from a curricular trajectory to an as yet unexperienced next activity) foster an appreciation for polycontextuality by

indexing both probably-relevant features of a new activity and decidedly-relevant features of prior experiences.

In conclusion, liminality and the design strategies of polycontextuality and prolepsis underscore an approach realized in the transitional activities studied in this dissertation. Each can contribute to the arrangement of mediational transitions along a learner's trajectory of participation and each serves a specific purpose. Liminality arranges an intermediate space between the present moment of a trajectory of participation and its possible future development; Polycontextuality guides the progressive recontextualization of the curricular experience in terms of the complementarity across contexts; and prolepsis defines a strategy for connecting the present and probable futures of a trajectory of participation within the context of a liminal space while also working to expand the learner's role therein.

Together, these strategies simultaneously attend to the learner's trajectory of participation as not only engaging in the meaningful practices of a system of activity but also his or her roles therein. Further, they can serve assessment for learning because they illuminate the empirical notion of transfer by means of mediational transitions that resonate with situative views of learning.

Assessment for Learning and of Knowing

Considering its different roles of assessment in science education, an NRC report (1999) entitled *The Assessment of Science Meets the Science of Assessment Standards* identified three main functions of assessment: (1) to monitor educational progress or improvement, (2) to provide teachers and students with feedback, and (3) to drive changes in practice and policy through accountability. These together reflect

conventional summative, formative, and accountability assessment functions respectively. The report also notes that summative and accountability assessments pervade schooling while more formative functions remain underdeveloped. Situative views of learning suggest a new perspective on educational assessment that not only features the formative functions of assessment as defined above, but underscores the formative functions of all assessment activities (e.g., Beach, 2003; Gee, 2003b; Greeno & Haertel, 2003; Hickey & Zuiker, 2003; Moss, Pullin, Gee, & Haertel, 2005).

If learning is situated, then any activity, including assessment, constitutes a learning experience of some kind. As particularly consequential educational practices, assessments often shape what is valued as learning in classrooms, in what ways that learning is valued, and, in turn, who learners are (Lave, 1993). Therefore, all assessments serve both formative and summative functions that shape and are shaped by the students, classes, and schools that engage them (e.g., Hickey et al., 2006). None of the assessments described in the NRC report above can, in effect, function as benign instruments for generating information when each valorizes or commoditizes particular, and often narrow (Lave & Wenger, 1991), displays of learning that typically foreground content knowledge at the expense of the contexts it serves. For example, the idea of erosion might serve as a means for answering multiple-choice questions rather than as a means of engaging problems in a watershed or as a farmer preserving fields. In this way, learners can exchange these displays independently of the actual use-value of learning. It is a pressing issue that assessment strategies address these undermining qualities by considering assessment more pervasively.

The idea of assessment for learning, then, reflects longstanding interest in the pervasive formative functions of classroom assessment at multiple levels. Reviews by Black and Wiliam (1998) and the NRC (2001) recognize the formative potential of assessment for both revealing individual understanding and supporting learning. Realizing this potential, however, depends upon how assessment is employed as feedback that is both useful and used. To these ends, educational researchers are only beginning to leverage assessment for learning in the context of technology-enhanced curricula such as educational video games (Federation of American Scientists, 2006).

The NRC (2001b) report *Knowing What Students Know* discuss efforts to develop useful and used feedback through assessments embedded in technology-enhanced curricula. One example that they feature considers assessment activities embedded within a problem-based water quality curriculum using the SMART tool (*Special Multimedia Arenas for Refining Thinking,* Barron et al., 1995). SMART diagnosed student data submissions related to river pollution and provided pointed feedback. In turn, it engaged students in diagnosing and providing feedback on pseudo-submissions laced with errors. The formative functions of the SMART tool and other embedded assessments have proven to be quite powerful both for promoting student learning and for subsequent revisions to curricular designs (NRC, 2001), which suggests the potential for embedded assessment in game-based curricula as well.

Embedding assessment in learning environments also spurs debate about the validity of the data they generate. Many forms of integrated or embedded assessment activities are highly contextualized by the curriculum, and the data they generate are often interpreted only with respect to the broader projects to which the activity relates

(NRC, 2001). Criticisms of such strategies target not only threats to the generalizability of results but also to the objectivity of analyses, illustrating an inherent tension around assessment data that are (too) closely tied to learning environments. These relatively "close" data fail to convince some educators and the broader public of the value of these innovative curricula. Without such data, the 2001 NRC report argues that it is difficult to expand the audience for these programs so that such programs are used on a larger scale. And yet, from a situative perspective, the constraints of conceptual tools such as conventional conceptions of validity and forms of standardized assessment such as the consensual position endorsed by AERA, APA, & NCME (1999) confound the conceptual tools necessary to understand phenomena (Beach, 1999; Moss, 1994). These tensions underscore an ongoing consideration of evolving theories of learning and their implications for assessment (Delandshere, 2002; Gipps, 1999; Moss et al., 2005; Moss, Girard, & Haniford, 2006; Pellegrino & Chudowski, 2003).

Arguing for a broader sense of validity in educational assessment, Moss and colleagues (2006) suggest that validity is always a situated process of interpretation, decision-making, and action. Measurement may be useful for developing a common argument across contexts and individuals but its "generative principles" (Greeno, 1989) preclude its use for developing more specific claims about what and how learning occurs within one particular context. However, when assessment is seen as an investigation (e.g., Delandshere, 2002) into not simply what is learned but how, and why, it is learned, then situative theories suggest different forms of evidence such as the language a student uses to make assertions and how it relates to a situation and in relation to a trajectory of participation. Importantly, these forms of evidence are considered in terms of both

evidence of learning as well as how generating such evidence shapes and is shaped by a learning environment. In light of situativity theories, this interpretation-decision-action process would ideally begin to consider learning in terms of doing science and being scientific in an activity system and, by the same token, consider how this process reflexively shapes learning. The embedment of assessment in game-based curricula that foster situative understandings, therefore, must be designed to appreciate a theory of learning that extends meaning across multiple situations. The aim in such a strategy is to provide opportunities to research how the curriculum functions in support of learning as both doing science and being scientific.

In conclusion, chapter 2 has presented the theoretical framework through which the general consequences of learning will be explored. Central to this view are the following two assumptions. First, learning is a relational activity and therefore knowledge is neither what is in the head nor what the head is in, but rather the ongoing transactions between them. Second, these transactions are a range of events that constitute networks of individual-environment affordances. From this perspective, the longstanding lines of research into transfer of learning can be recast in terms of transitions that expand learning. This dissertation leverages a common transition, described by Beach (1999) as mediational transitions, in order to conceptualize liminal transitions along learners' ongoing trajectories of participation. The second part of the chapter presented theoretical underpinnings for the construct of liminal transitions. This construct reflects Wenger's notion of participation as the complementarity between practice and identity. In general, liminal transitions arrange activities that emerge in between recurring cycles of participation, reflecting Turner's (1967) ontological

innovation—liminality. Liminal participation engages learners in practices with complementary contexts to foster polycontextuality. Liminal participation simultaneously engages learners redefining their roles in terms of prolepsis. Finally, the chapter considered forms of assessment that support learning and reveal knowing. Liminal transitions can accomplish both ends, providing a useful strategy for a new generation of game-based curricula and design for evolving theory about the general consequences of learning. In the next chapter, these ideas are translated into a methodology for investigating and refining liminal transitions.

CHAPTER 3

METHODS

Overall Approach and Rationale

As an example of design-based research (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Kelly, 2003; Bielazyc, 2006), this study aims to examine and refine an innovative strategy for supporting and understanding the general consequences of learning in game-based curricula by means of an "interventionist" methodology (Cobb, DiSessa, Lehrer, & Schauble, 2003). The intervening manipulations that comprise a design-based approach aim "to investigate the possibilities for educational improvement by bringing about new forms of learning in order to study them" (Cobb et al., p. 10). Alternative approaches to educational research often attempt either to control an experience for causal analysis or to preserve it for naturalistic study. While these contrasting approaches inevitably view intervention as a compromising feature, design studies view such intervention as an essential component for successively approximating new forms of learning in order to develop theoretical understanding. This process ideally illuminates the relationships between classroom communities and meaningful design features. In this way, the present study aims to contribute a use-inspired innovation that both advances situative theories of learning and enhances teaching and learning environments through practices that reveal and support ongoing participation beyond a specific curricular experience.

Statement of Purpose

The purpose of this dissertation is to explore the general consequences of learning from a situative theoretical perspective using video game-based technologies and methodologies (Brown, Collins, & Duguid, 1989). It considers how transitions from central curricular activities to complementary, peripheral activities support the general consequences of learning. By designing these transitional activities in relation to the paired notions of practice and identity (Wenger, 1998), it translates situative theory into practice in order to evolve theoretical understanding and refine design principles.

Research Questions

RQ1. How can transitional experiences within and across a digital game-based curriculum and different but complementary situations to which the curricular experience might extend reveal knowing and support learning?

RQ2. What principled design strategies might guide the development of game-based transitions complementary to game-based pedagogies? Specifically, how might transitional experiences both support ongoing trajectories of participation and reveal discrete moments of knowing about domain practices?

RQ3. How do such transitional experiences compare to traditional forms of formative assessment in supporting and revealing the general consequences of learning (e.g., transfer and alternative views of transfer)?

Participants

This study considers two design-based research implementations, which took place in three classrooms at two elementary schools located in the same US midwestern town. One classroom of twenty-two fourth grade students labeled as "gifted" used the

curriculum at the beginning of their second semester at one school; and one month later two sixth grade science classes (taught by one science teacher) used a revised version of the curriculum concurrently at the other school. Both teachers were familiar with the specific curriculum and broader web-environment known as Quest Atlantis (QA), and both had taught with an earlier version of this curriculum in previous years (Barab et al., 2005).

This study focuses primarily on the latter sixth grade class of twenty-six students because this class enacted the second iteration of the design. Further, this class could be contrasted with a comparison condition in another class taught by the same teacher. This study's aim is to understand how transitional experiences about and beyond the curriculum support learning and reveal knowing (RQ1) and what these implementations suggest for developing game-based design principles (RQ2). It also aims to evaluate learning across two sixth grade classes in order to understand how these transitional experiences compare to more traditional transitions arranged by formative assessment activities (RQ3). While the fourth grade classroom's participation in the study informed the ongoing iterative refinement of the curriculum, the students represent an exceptional learning community that obscures many of the broader challenges of schooling. Precisely because this study aims to develop principles that extend beyond the local context of a focal classroom, this unusual group serves only a secondary role in the analysis that follows in chapter 4.

Curriculum

Quest Atlantis MUVE

The curriculum is situated in a 3D multi-user virtual environment (MUVE) known as *Quest Atlantis* (QA). Building on the designs of online role-playing games, QA combines strategies used in commercial video game environments with lessons from educational research (Barab et al., 2005; Barab et al., in press). It enables participants to customize a virtual character known as an avatar, which moves in and between virtual "worlds' allowing players to interact with one another and to engage in entertaining and educational virtual experiences. These experiences are generally organized around shorter-term tasks known as "Quests" nested in longer-term units known as "Missions".

QA also develops an elaborate background narrative. Books and comics develop stories about a mythical world in danger of collapsing. Among other things, these narratives discuss the "Council of Atlantis" and its commitment to ideas like "environmental awareness" and "social responsibility". A fictional council member oversees each commitment. "Lan", for example, is the name of the council member responsible for environmental awareness. He has a blog and website on QA that feature discussions and information about the environment.

The Taiga Fish Kill Project

The specific QA curriculum featured in this study is a game-based inquiry experience called *The Taiga Fishkill Project*. This curriculum was designed, implemented, and refined through previous work (Barab et al., 2006; Barab et al., in press) and was further refined for this study. The central science content revolves around formalized scientific understandings and science learning standards. The five targeted understandings are

erosion, eutrophication, water quality indicators (e.g., turbidity, dissolved oxygen), watersheds, and formulating and evaluating a hypothesis. The four targeted Indiana Academic Standards (http://www.indianastandardsresources.org) appear in Table 3.1. The narrative and perceptual context, meanwhile, embed this science content within an ecological problem created within one of QA's 3D virtual worlds called Taiga National Park (hereafter Taiga) and the characters that "live" there.

TABLE 3.1

Science learning standards targeted in The Taiga Fishkill Project *curriculum*

Standard	Description
1.	**Scientific Inquiry:** Begin to evaluate the validity of claims based on the amount and quality of the evidence cited.
2.	**Technology and Science:** Explain how the solution to one problem, such as the use of pesticides in agriculture or the use of dumps for waste disposal, may create other problems.
3.	**Systems:** Recognize and describe that systems contain objects as well as processes that interact with each other.
4.	**Models and Scale:** Demonstrate how geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representation can never be exact in every detail.

In the curricular narrative, Taiga faces the problem of declining fish populations and the looming ecological disaster that it suggests. Learners investigate the fish problem through a progression of "Missions." Each Mission is a list of goals that students complete through a series of activities in the virtual space (e.g., talking to a character, collecting water samples) and through various writing tasks. Some of these writing tasks prompt brief responses (2-5 sentences) called "text box dialogues", which students typed during interactions with NPCs online; others are more elaborate short essays (2-5 paragraphs) called "Quests." The complete set of written and activity-based mission goals

constitutes a general pathway through the curriculum. This path is relatively closed and inflexible at times. Such is the case for a Mission 2 task that requires all students to collect three water samples. However, the pathway is relatively open and flexible for the writing tasks and some other activities. For example, each student formulates a unique hypothesis and solution, and each makes decisions (i.e., selecting polite or impatient responses) that differentiate their experiences. Therefore, as students engage tasks along this curricular pathway, they also make choices that create differences and develop interpretations that together build unique trajectories of participation with the curriculum.

The curricular pathway defines an explicit temporal progression, but it is not necessarily a linear progression through scientific content. Students' choices along the same pathway reveal the fish problem differently and mean that different content becomes relevant at different times. For example, the first two primary Missions are set in the year 2007 and the last two are in the years 2009 and 2022 respectively. Importantly, each student must make a critical decision at the end of Mission 2 that determines which of three possible scenarios follows in Mission 3. Figure 3.1 overviews this progression.

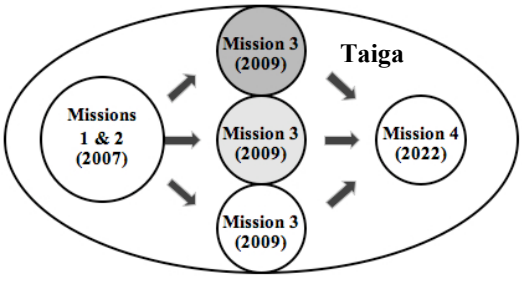


Figure 3.1 Diagram of the primary missions for *The Taiga Fishkill Project* curriculum.

Circles represent missions, arrows illustrate the three possible pathways students might take in order to complete Mission 3 and progress to Mission 4, and the ellipse represents

the Taiga context in which all missions are embedded. Each possible Mission 3 presents an entirely different virtual environment that reflects how a student made sense of the fish problem. In this way, as class time passes, students proceed through the same curricular pathway but it can become meaningful in different ways.

The trajectories of participation arranged by these Missions evolve with respect to authentic scientific practices (e.g., analysis of water quality indicators) and roles (e.g., field investigator) in a scenario with physical and social dynamics. As the curriculum unfolds, students can see physical changes in the park, measure chemical changes in the water; and "gather" facts and opinions through interviews with Taiga characters. Taiga characters, like actual QA players, take the form of 3D avatars but only respond as programmed by the research team. Although they are, in effect, non-player characters (NPCs), their dialogues with players play out differently depending on what students choose to "say" and on what decisions they make about the fate of the park. Altogether, these visual, data, and narrative features are leveraged to support scientific inquiry and problem-solving. Students initially develop hypotheses based on what they see and "hear". Next, they generate and analyze scientific data in light of the ecological sustainability as well as the social and economic tensions of the Taiga groups. Finally, they attempt to balance the scientific information and the social systems in order to resolve the fish problem and reconcile the activities that disrupted the ecosystem in the first place.

The curricular experience requires between ten and fifteen 50-minute class periods. In addition to the virtual environment, the curriculum also includes a paper-based introductory letter from the park ranger and field investigator notebook that helps

structure note taking in preparation for writing Quest responses. Table 3.2 details the overarching structures and underlying theoretical inspiration for the pathway through the four main missions—Missions 1, 2, 3, and 4—and the two secondary missions – Missions 2.5 and 3.5 - that serve as the liminal transitions considered in this dissertation.

TABLE 3.2

Overview of missions in The Taiga Fishkill Project *curriculum*

Mission	Overview	Theoretical Inspiration
1	Find and interview NPCs about activities and perspectives on different Taiga groups	Establish rich perceptual and narrative grounding; foster analytical stance on problem
2	Analyze scientific data, propose a solution to the fish problem, and identify one group to blame	Enlist scientific concepts to recast narrative in terms of erosion and eutrophication
2.5	Analyze diagrams and a proposal related to Taiga	Interpret Taiga narrative with respect to alternative Taiga situations
3	Interview NPCs and explore Taiga two years in the future then explain why blaming just one group did not solve problem	Use narrative and science to appreciate interconnectedness of human activities and watersheds
3.5	Analyze evidence and proposal related to Atlantis but not Taiga	Interpret Taiga narrative and scientific concepts with respect to alternative, broader Atlantian situations
4	Interview NPCs and explore Taiga 15 years in future then explain success of present solution	Enlist interconnectedness of social and scientific activities to appreciate complexity of sustainable solutions

Problem Scenario

Students begin by reading an introductory letter and urgent plea from a Park Ranger, Ranger Bartle. Because the fish are dying, Ranger Bartle drafts an open letter to "field investigators", soliciting an inquiry into the social and scientific underpinnings of

the problem with hopes that it can help him find a solution (See Appendix A). This letter provides a map of Taiga (see Figure 3.2) and begins to build a narrative context that continuously unfolds throughout the curriculum.

Figure 3.2 Two-dimensional map of Taiga National Park featured in *The Taiga Fishkill Project* curriculum.

Students also receive an 18-page letter-sized "field notebook" after reading the introductory letter. The notebook presents guiding questions about the letter and organizational structures for taking notes during the four main Missions. Pages related to the first Mission, for example, list each of the Taiga NPCs with adjacent spaces to record their group membership (e.g., loggers) and what the character says during interviews. After reading the introductory letter and providing written responses to field notebook questions, students ideally begin to appreciate the fish problem and what they need to find out in order to solve it.

Mission 1: Getting a handle on Taiga

Students enter Taiga as Ranger Bartle's newly hired investigator and begin interviewing thirteen characters interspersed throughout the park (see Figure 3.3). Each is affiliated with one of the park's five main groups—a logging company, a sport fishing outfit, an indigenous farming community, tourists, and the park rangers. By clicking on an NPC, players trigger a dialogue with multiple possible responses. Depending which of the pre-determined options the student selects an interview unfolds differently. Each branch of the dialogue tree ultimately addresses similar information, however it is conveyed differently depending on the tone of the chosen response, for example. As players engage characters for the first time, dialogues address them as newcomers and, only later, as someone with whom they are familiar. In this sense, the conversations position players in some ways and not others, and this positioning unfolds across time. By interacting with NPCs in this way, students learn about the park, the groups, and the declining fish population therein. In addition to interviews, students also engage the perceptual richness of the 3D Taiga world. Together, its characters and its environment highlight a situation that students can explore differently in order to gain a rich appreciation of the happenings in Taiga. At the end of Mission One, each student formulates an initial hypothesis about the fish problem, which they type and submit online to Ranger Bartle. This submission is their first quest (Quest 1), and after review written feedback is returned by the classroom teacher under the guise of Ranger Bartle.

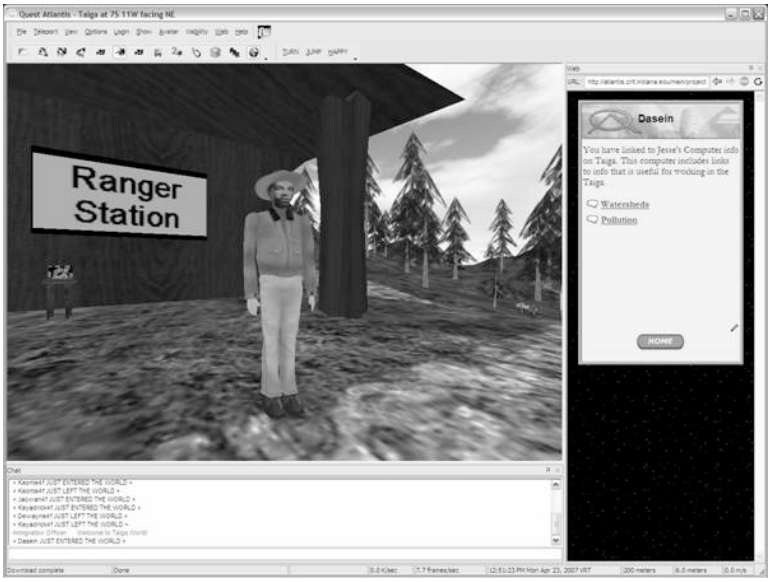


Figure 3.3 Screenshot of the Quest Atlantis multi-user virtual environment featuring the virtual world Taiga National Park

Mission 2: Helping Bartle

As field investigators, students collect and analyze Taiga water samples. They then interpret water quality data tables in order to explain the relationships between (a) six indicator values (e.g., temperature and turbidity levels), (b) human activities influencing the fish decline (e.g., farming and logging), and (c) scientific processes underlying the fish decline (e.g., eutrofication and erosion). For Quest 2, students typed and submitted their interpretations of water quality data. Moreover, they were challenged to explain which activities at each water collection site may have caused the water quality data to be as it was and how the data across all sites might be inter-related (Quest 2). Given the central importance of understanding the ecological interdependence underlying Quest 2, students could not complete the second Mission if the teacher did not approve their submission. To assist students in the revision process, the Taiga laboratory technician NPC provided elaborate advice about Quest 2 to students who visited him. Importantly, this feedback activity task constituted a separate research study being

conducted by a different researcher. The specific design of the study was negotiated between researchers to ensure that feedback design remained consistent with the situative theory and game-based pedagogy underlying the curriculum.

In the next mission task, Ranger Bartle asks students to re-evaluate the hypotheses they previously submitted as their first Quest in light of their newfound interpretations of water quality data. Finally, after completing all Mission 2 requirements, Ranger Bartle asks each student to blame either the logging company, the fishing outfit, or the indigenous farming community for the fish decline. A mythical Atlantian council member then sends the student/field investigator into the future to find out what happens to Taiga.

Mission 2.5: Helping Jesse (First Liminal Transition)

Students encounter the first liminal transition in a series of activities that run parallel to Mission 2. Mission 2.5 begins with a plea from a new Quester in QA, an NPC named Jesse. Like the students, Jesse works for Ranger Bartle but cannot complete his assigned Quests. He therefore asks students to help him. Continuing in their role as field investigators, students work through the two Quests that Ranger Bartle delegated to Jesse (Quests 2.5A and 2.5B - see the text of these Quests in Appendix B). The first Quest presents three diagrams. Jesse explains that scientists who previously examined Taiga's fish problem drew these diagrams to explain the problem. Each one depicts objects and processes relevant to activities of the logging company, sport-fishing outfit, and indigenous farming community respectively (see farming and logging diagrams in Figure 3.4).

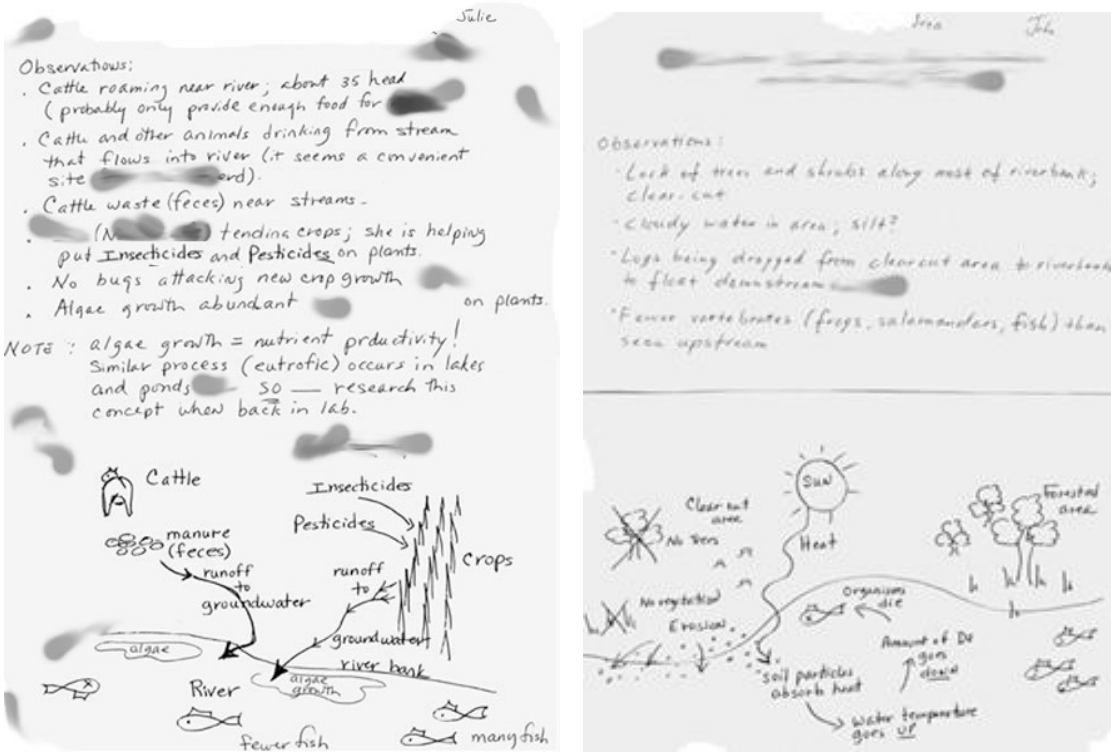


Figure 3.4 Farming and logging diagrams featured in Mission 2.5

In connection to the farming diagram in particular, the second Quest requires students to evaluate a proposal to expand the indigenous farming communities' farm along the edge of the river. Students must decide if the proposal creates new problems and then advise Ranger Bartle accordingly. After explaining the scientists' diagrams and evaluating the farm expansion proposal, Jesse thanks students and suggests that they talk with Ranger Bartle again.

This mission is different from the preceding two missions for several reasons, and these differences reflect the theoretical constructs discussed in chapter 2. First, the context of this Mission presents tasks differently because students work *with* another Quester and not *for* Ranger Bartle directly. Moreover, it is a plea. This plea suggests that the student is a different kind of Quester than Jesse, specifically one who can help him to complete his Quests. Jesse's request presupposes that the learner is not only a Taiga field

investigator, but one with greater competence. Therefore, by featuring this situation with Jesse, the design attempts to induce students' presuppositions about their own relative competence (see chapter 2 for a theoretical discussion of the notion of prolepsis). Rommetveit (1974) suggested that such presuppositions might also trigger a kind of anticipatory comprehension. Relative to this situation, presuming the learner's higher degree of competence may also suggest that Jesse's Quests are the ends that justify these presupposed means. In doing these quests students enact the competence implied by the situation itself.

Mission 2.5 is also different from the prior two because the two scenarios represented in the Quests introduce new representations of and information about Taiga. At the same time, these diagrams and the farm expansion proposal are embedded in the narrative as a recently investigated problem and a proposed solution in Taiga, respectively. In this way, the scientific perspectives reflected in the diagrams and the hypothetical scenario detailed in the proposal both provide different contexts that, at the same time, remain complementary to the Taiga context. The balance of difference and complementarity here may provide students with opportunities to think about and beyond present-day Taiga. That is, the different situations may provide opportunities to think with the present-day Taiga experience to understand other interpretations of it. In doing so, the present and recent past Taiga, together, foster a polycontextual appreciation for scientific practices underlying both such as the interpreting the process of eutrophication depicted in the farm diagram in Figure 3.4 (see chapter 2 for a theoretical discussion of polycontextuality).

Mission 2.5 represents a mediational transition (Beach, 1999) because it engages learners with "as if" scenarios. Each scenario specifically presents complementary situations embedded in the same Taiga context as the curriculum. These scenarios also leverage the continuity of the game players' roles to suggest their increasing competence. Together, presupposing the game players' competence with different but complementary problems arranges unique activities along the pathway through a gaming curriculum. These activities occur "in-between" the normal Taiga missions and in-between a trajectory of participation, interleaving a learner's present moment and possible future developments along this trajectory. These activities constitute liminal transitions that aim to engage learners with ways of doing science and being scientific. Further, the two Quests illuminate general consequences of learning and knowing in terms of productive transitions. In leveraging the learner's emerging disciplinary role and developing practices, they also aim to support learning by providing opportunities to transform participation with respect to complementary disciplinary contexts.

Mission 3: Following up with Bartle

In this mission, students explore Taiga two years in the future. While the circumstances have changed, Taiga's problems still persist. No matter which group a student blamed, the simple solution will have failed, albeit differently. The underlying reason for that failure, however, remains the same across all three: scientific reasoning isolated from the broader social systems that it serves underdetermines solutions to the range of issues associated with the declining fish problem. This disconnect is revealed through changes in the virtual environment and new dialogue with characters from each group who highlight not only scientific but also political and economic factors that

contributed to the ongoing ills of the park. Solving the fish problem now requires students to reconcile social and scientific issues. Therefore to conclude Mission 3, each student submits an explanation of (a) why blaming one group created a new set of problems and (b) how she might solve the problems (Quest 3).

Mission 3.5: Working with Lan (Second Liminal Transition)

Near the end of Mission 3, students receive a letter that instructs them to pair up in order to coordinate entry into a Taiga cave. Once inside, they meet with the Atlantian council member in charge of "environmental awareness"—the NPC Lan. Impressed with the students' work, Lan recruits each pair of field investigators to help him solve problems elsewhere in Atlantis. He provides secret codes to unlock two different meeting rooms, and each room contains a different report. The first asks students to evaluate evidence in order to determine the best type of water filter, and the second asks them to evaluate the solution that a town has proposed about a factory's pollution problem (see text of both reports in Appendix C). Lan advises each pair to share their opinions on the reports and to negotiate a shared solution before typing their individual responses. In this way, the Mission aims to foster peer discussions about scientific problems.

This mission presents a second liminal transition because the reports and the context through which they are presented (e.g., the Taiga cave, a council member) neither clearly relate to the primary Taiga missions nor clearly dissociate from them. In contrast to Mission 2.5, however, the Mission 3.5 reports link to Atlantian situations beyond Taiga and not within it. That is, the first liminal transition is embedded in the Taiga scenario and its history (e.g., prior work of scientists) while this second liminal transition is linked to the broader community and contexts of Atlantis (e.g., ongoing work of the

Atlantian Council). Mission 3.5, like Mission 2.5, therefore designs for polycontextuality by introducing different but complementary contexts. The overlapping aspects of these situations provide opportunities to negotiate the meaning and function of practices across multiple other contexts. Mission 3.5 also designs for prolepsis. This mission, like Mission 2.5, entails a repositioning of students that presupposes increasing competence. In this case, Lan's request implies that the Taiga missions demonstrate the student's increasing competence and, in turn, presupposes that subsequent participation with the council reports can be understood in terms of preceding participation with the Taiga missions. Altogether, these polycontextual affordances combine with the presupposition and anticipatory comprehension induced by prolepsis to support liminal transitions about and beyond the immediate Taiga activities and context. Figure 3.5 illustrates the relations between both the secondary missions with respect to the four primary missions presented in Figure 3.1.

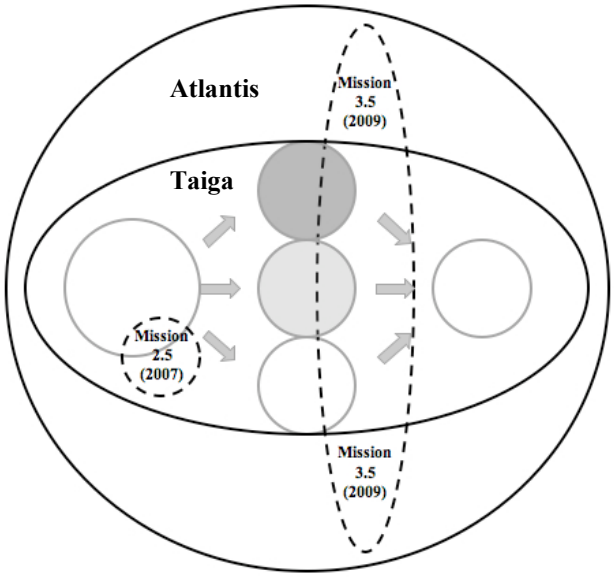


Figure 3.5 Diagram of the primary and secondary missions for *The Taiga Fishkill Project* curriculum

Reflecting Figure 3.5, liminal transitions are embedded in Taiga for Mission 2.5 and linked to Atlantis for Mission 3.5. Both transitions remain liminally connected to the primary Taiga missions by simultaneously maintaining continuity with the learner's role as a Taiga field investigator and transforming the competence with which the role is positioned. In this way, liminal transitions reveal knowing in terms of productive mediational transitions and support learning by framing participation in terms of learner roles. Table 3.3 provides an overview of each transition in terms the ways it arranges polycontextuality and prolepsis as well as the targeted science content that each addresses.

TABLE 3.3

Overview of Design Features and Targeted Content for Liminal Transitions

Liminal Transition		**Polycontextuality Design**		**Prolepsis Design**		**Targeted Science Content**
Mission 2.5	Quest 2.5A: Diagrams	Embedded in Taiga scenario	Preceding scientific interpretations of other scientists	Presupposing competence of Taiga field investigator	New Quester solicits students to help with two Quests from Taiga's Ranger Bartle	Erosion, Eutrophication, Standard 3
	Quest 2.5B: Proposal		Preceding solution proposal of local indigenous farming community			Eutrophication, Standard 2
Mission 3.5	Report: Water Filters	Linked to Atlantis scenarios	Polluted drinking water downstream of Taiga		Environmental leader recruits student to advise Council of Atlantis on two reports	Hypothesis, Standard 1
	Report: Bluegill Stream		Solving chemical pollution problem along a different stream			Water Quality Indicators Standard 3

Mission 4: Beyond Bartle

In the final mission, students travel thirteen years further into the future in order to explore a healthy and balanced Taiga and to conduct interviews. Ranger Bartle has, at this point, resolved the fish problem and struck a balance between the community needs

and ecological constraints. At the same time, students learn that the implemented solution may or may not reflect their particular recommendations. Therefore, they again talk to characters, inspect the virtual landscape, and report to the Atlantian Council exactly which changes occurred and how they reflect a socio-scientific solution (Quest 6).

Multi-Level Assessment of Individual Learning

In addition to the activities detailed in the previous section, students completed three pre/post pencil-and-paper assessments of science content understanding less than one week prior to and following the curriculum. These assessments are grounded in distinctions that define an assessment continuum in terms of referent generality (Snow, 1974). The idea of referent generality simply recognizes that any bounded real-world event, including experiments, can be considered in terms of the different data that various instruments generate. Further, these instruments (i.e., surveys and assessments) can reference an event more or less generally. This means that not only can different methods generate different data, but a single method can generate data with different degrees of generality. This latter generality is determined by how closely the representations in the instrument refer back to the bounded real-world event under consideration. One example is near- and far-transfer measures, which typically reference the apparent, or surface, features of an initial learning event more and less.

Referent generality has been enlisted to consider educational assessment and evaluation in terms of instructional sensitivity (Ruiz-Primo, Shavelson, Hamilton & Klein, 2002). In this case, instruction around a curricular unit constitutes the bounded event under consideration. An important assumption about a curriculum is that it enlists particular representations of content (e.g., textbook passages, charts, experiments) and

arranges specific activity structures through which it is engaged (e.g., reading, lecture, inquiry). Given this range of possibilities, an assessment can, in turn, collect artifacts of instruction (e.g., student notebooks, essays, and calculations) and develop a wide range of assessment items that represent the targeted content differently. Altogether, these generate data at different "distances" from immediate events of classroom instruction. For example, an exam about a curricular unit, a high school graduation accountability measure, and a subsequent college course placement test would likely relate less and less to the classroom lectures and discussions, student notebook entries, and textbook passages that they aim to assess. At the same time, each reflects the immediacies and particulars of instruction with some relative degree of instructional sensitivity. Ruiz-Primo et al. (2002) defined five levels of instructional sensitivity as *immediate*, *close, proximal*, *distal*, and *remote*. Each increasingly distant level is less sensitive to specific forms of instruction. Ruiz-Primo and colleagues also contend that each level is multi-faceted because different instruments as well as additional non-instrument data sources reveal learning and contribute to an understanding of the effects at and across levels.

Building on the notions of referent generality and instructional sensitivity, Hickey, Zuiker, and colleagues developed a multi-level assessment framework that organizes a range of conventional strategies for understanding the general consequences of learning (Hickey & Zuiker, 2003; Hickey et al., 2006). This framework enlists assessment practices that fall into Ruiz-Primo and colleagues' proximal and distal levels and that typically operate along the longer cycles, or timescales (Lemke, 2000), of schooling (i.e., semesters, school years). Assessment practices at both levels are framed in terms of classroom practices that operate along shorter cycles of activity (i.e., lessons,

units). Together, data across levels define one kind of continuum for understanding the generalization of learning.

Each assessment detailed below, and other data collected, fall within the proximal and distal levels of Hickey and colleagues' multi-level assessment framework (Hickey et al., 2006) and complement immediate- and close-level data detailed later in the chapter. These data combine to define a continuum for understanding learning about the science content and learning standards targeted in the curriculum.

Curriculum-Oriented, Proximal Performance Assessment

The proximal performance assessment asked questions about a watershed with similar features to Taiga. It also depicted a similar scenario in which various human activities occurred at or near the riverbanks and from which similar water quality analyses were provided. Fifteen constructed-response questions and six multiple-choice items required students to examine the watershed ecology in terms of the image and scenario each provided. Questions required students to evaluate the evidence presented, the systemic relationships between various objects and processes related to the watershed ecology, and either the consequences of identified problems or the student's own prospective solutions to them, thus reflecting the target content and standards. Due to the rich detail and salience of the assessment, different versions were administered before and after the curriculum. These versions presented the watershed 10 years apart and incorporated different human activities and water quality data.

Curriculum-Oriented, Proximal Multiple Choice Assessment

Nineteen multiple-choice items assessed the target content and standards in terms of the same concepts and similar ecology contexts. Unlike the performance assessment

above, these items each drew upon different and more abbreviated problem contexts. The descriptions and representations in each question resembled key curricular features, but the items themselves originated from released items associated with state and national standardized testing initiatives. For example, Figure 3.6 shows a proximal-level representation used to assess the concept of erosion relation. It features the same elements and processes of a watershed such as trees, rainwater runoff, and erosion, but in terms of a watershed and ecological consequences that differ from the curriculum.

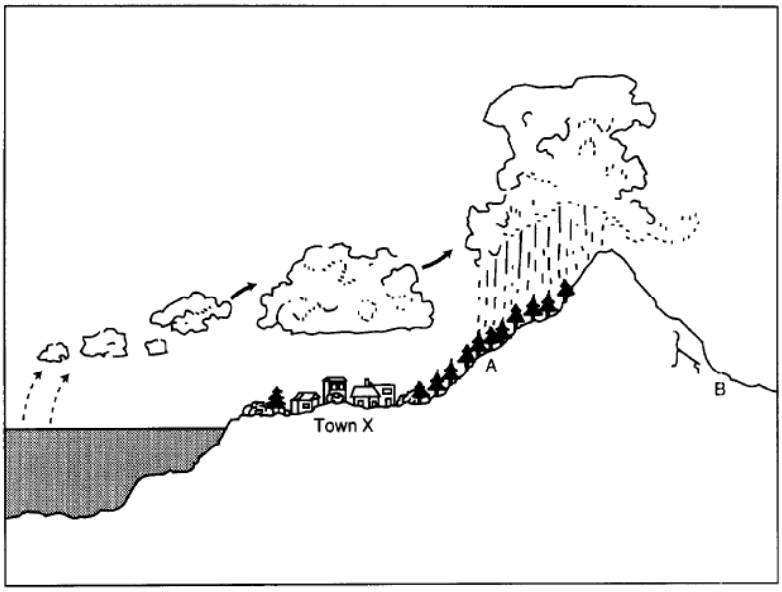


Figure 3.6 Example of a possible proximal-level representation of the concept of erosion as targeted by the Taiga curriculum

Standards-Oriented, Distal Multiple Choice Assessment

The final instrument features twenty multiple-choice items that assess the target content standards independent of the curricular context and the particular content. In this way, the assessment attempts to measure learning in terms of the invariant properties underlying the curricular context and content. The descriptions and representations for each items are intended to vary independently of the curriculum by changing the particular system in which these properties are invariant (e.g., ozone depletion within the

atmosphere as opposed to soil erosion on land) or presenting the content abstractly (e.g., a decontextualized soil experiment as opposed to one similar to that which the students encountered in the curriculum). As with the proximal level multiple choice assessment, items derive from a pool of released items made available by state and national testing initiatives. As an example of distal representation, Figure 3.7 shows watering cans and combed mounds of sand that aim to address the target standard concerned with interactions between objects and processes in a system, specifically in terms of abstract notions of erosion and the hydrologic cycle. As these three assessments illustrate, learning cam be represented at multiple levels of generality. Each affords a different perspective on the curriculum and the general consequences of learning. The two study designs included in this dissertation will now be discussed in more detail.

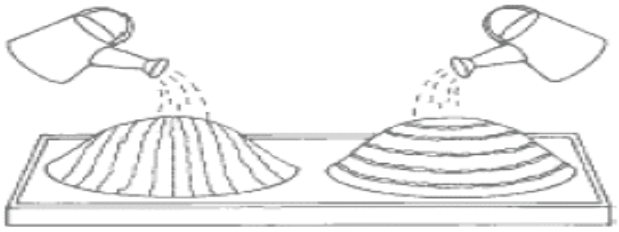


Figure 3.7 Example of a possible distal-level representation of the concept of erosion as targeted by the Taiga curriculum

Study One Design

Recall that this dissertation featured studies in one fourth and in two sixth grade classes. In study one, the fourth grade class enacted *The Taiga Fishkill Project* curriculum without manipulation. The aim of this study was to understand the general ways that students engaged liminal transitions and the curriculum as a whole as well as to troubleshoot design issues and programming errors. While the entire curriculum had been pilot tested by four elementary-level volunteers one week prior to beginning the study,

this fourth grade class presented the first realistic opportunity to use the revised curriculum. For these reasons, study one represented an important informal precursor to the broader and more formal focus in study two.

Study Two Quasi-Experimental Design

In Study Two, two 6th grade classes enacted the Taiga Fishkill Project curriculum with manipulation. Study Two represented a more formal consideration of game-based trajectories of participation and the role that liminal transitions might play therein. While the study primarily focused on student participation (RQ1 and RQ2), it additionally considered the differential effects of liminal transitions and conventional formative assessment (RQ3). In order to address this question, two classes completed different curricula that incorporated a quasi-experimental design of two transition conditions: one featuring liminality and one featuring a conventional formative assessment. The differential effects of these conditions were considered by means of the multi-level assessment measures described above.

The first condition presented liminal transitions as secondary missions embedded along the curriculum's designed pathway as described in the curriculum section above. The second condition featured formative assessment activities that interleaved the game-based curriculum with pencil-and-paper assessments. Both conditions provided feedback on two of the target standards (standards 1 and 2 in Table 3.3) but, as the descriptions below will show, they relate differently to curricular trajectories of participation. (The obvious omission of a control group in this design reflects overwhelming evidence of the value of "assessment for learning" (Assessment Reform Group, 1999; Black & Wiliam, 1998; NRC, 2001) and feedback in general (Hattie & Timperley, 2007). The outstanding

challenge therefore is to design feedback that is both meaningful and meaningfully engaged by students.

Conventional Formative Assessment Condition

In the formative assessment condition, students completed paper-and-pencil quizzes that presented a series of multiple-choice and constructed response questions. Questions presented contexts different from but complementary to the curriculum that afforded opportunities for students to negotiate the meaning of curricular practices across multiple contexts. In this way, the formative assessment condition provided opportunities to appreciate polycontextual affordances of the target content. At the same time, while these questions related to the curriculum's targeted content and standards, they did so without direct relation to a student's trajectory of participation. That is, questions bore no explicit relation to the curricular narrative or the field investigator roles that students assumed as part of the curriculum. In this way, the quizzes represented mediational transitions that engaged students with targeted content but without framing the transition in terms of their ongoing participation with the curriculum or the curricular context.

Quizzes were informal and ungraded, and students individually completed one quiz each after Missions 2 and 3 (see mission quizzes in Appendix D). Typically, the researcher handed individual students a quiz after the teacher indicated that they completed either mission 2 or 3. Students were asked to briefly interrupt their participation in the curriculum in order to complete the quiz. Completed quizzes were collected, and students received feedback within two class periods. Feedback was pre-written by the research team and came in the form of brief paragraphs that explained the solutions to each question. This prose did not answer the questions directly but rather

explained the general reasoning or conceptual understandings underlying each question. After reading the feedback, students were asked to re-evaluate their responses and to voluntarily make changes to improve their solutions. In sum, the quizzes and feedback provided in this formative assessment condition arranged mediational transitions with respect to scientific practices but without framing these questions with relation to the curriculum.

Liminal Transitions Condition

Missions 2.5 and 3.5 represent the game-based mediational transitions that arrange different but complementary contexts. In addition, both missions are designed as liminal transitions that occur within and across students' trajectories of participation. Like the conventional assessment condition described above, these mission activities present complementary contexts that afford students opportunities to transform their participation with respect to the polycontextual affordances of relevant other contexts while maintaining continuity with learners' roles as Taiga field investigators.

By framing students' participation in terms of both disciplinary practices (i.e., evaluating the health of ecosystems) and disciplinary roles (i.e., ecologist, laboratory assistant), liminal transitions relate to previous activity, promote polycontextuality, and suggest both a possible future and a broader scientific community. Specifically, it is assumed that the degrees of continuity and transformation provided by embedding learners' activities somewhere between the recurring Taiga Missions (i.e., liminality) and implicitly repositioning their role therein—in terms of the increasingly competent status that helping a new Quester and working with an esteemed member of the Council of Atlantis can connote (i.e., prolepsis)—imbue these contexts with meanings that anticipate

the relevant content. In a sense, the relevance of learner roles entails an as yet unknown relation between a new situation and the curriculum, triggering anticipatory polycontextualization. In sum, liminal transitions (1) are complementary to the curricular trajectory (affording polycontextuality), (2) are ambiguously entail the present trajectory of participation (designing for prolepsis), and (3) extend the curricular context while maintaining continuity with the learner's role therein (establishing liminality in a trajectory of participation).

Data Collection

As a kind of case study (e.g., Yin, 2003), this dissertation gathered comprehensive, systematic, and in-depth information about liminal transitions within a game-based curriculum. Where to look and what to focus on were both determined by the researcher's theoretical commitment to a situative perspective on learning (e.g., Lave & Wenger, 1991). Theories of situated cognition "see" learning in terms of the functional relations between individuals and their physical and social environments. These relations are fundamentally realized through individual-environment transactions, or events. In this dissertation, events are assumed to render concrete and observable the processes that construct "what counts" as doing science and being scientific within curricular boundaries and thereby define trajectories of participation. In order to generate data about classroom events, the researcher documented activities and collected artifacts by means of an ethnographic approach (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005; Spradley, 1980). Specifically, the researcher experienced the classroom enactments through

participant observation, enquired into students' experiences through interviews, and subsequently examined a range of artifacts generated by participants.

Multiple methods were used to collect a range of qualitative data. Together with the multi-level assessment measures discussed earlier, these data reflect a "concurrent nested" design (Cresswell, 2002). In this sense, all data were essentially collected concurrently during the enactments, but the quantitative measures of individual learning gains (RQ3) were nested in the broader qualitative inquiry examining ways that students, as part of social systems, enacted a curriculum as a process of meaning-making (RQ1 and RQ2). This section therefore describes the qualitative data sources enlisted to this end and the role each serves in understanding how students, teachers, and the gaming environment together constitute the enactment of a science curriculum. These details follow after a brief discussion of the researcher's role during classroom activities.

Researcher Role

The researcher was a participant observer during all class periods of *The Taiga Fishkill Project*. In this role, he offered suggestions, guidance, and support in response to student or teacher questions about both the technologies and the curriculum while, at the same time, documenting and inquiring into classroom participation. Two other researchers consistently supported the implementation and, across the two-month span of data collection, three additional researchers intermittently substituted when time conflicts arose. The author also observed multiple period-long science activities in each teacher's classroom in the days and weeks leading up to each study. These visits provided a brief

glimpse into the learning ecologies that teachers and students had created during their first semester together and provided an opportunity to learn students' names and faces.

The researcher also met briefly with both teachers prior to implementations. These meetings helped coordinate the timeline and logistics of each study and also provided opportunities to discuss game-based pedagogy, preview changes to the curriculum that occurred since their previous experiences, and answer questions the teachers had about either one of these. The dates, topics, and duration of site visits before and during each study are detailed in Appendix E in Tables E1 and E2.

Fieldnotes

The researcher observed classroom participation across the curricular enactments and documented conversations and observations in 108 pages of a half-letter size (8.5" x 5.5") notebook, or roughly 54 hand-written pages of fieldnotes. Hand-written observational fieldnotes that had been necessarily abbreviated by the pace of classroom activities were transformed into more elaborate records by expounding upon written entries while typing them into a word processing document. They also added initial analytical notes that marked potentially significant happenings and began to conceptualize daily observations in terms of students' trajectories of participation with the curriculum. These elaborations were also informed by the research team's ongoing discussions after class periods, at meetings on the university campus, and via email and phone.

Audio-Video Recordings

The research team recorded all class periods for both studies. Four recorders generated "mpeg3" audio files and three cameras generated "mpeg4" video files. One

camera was dedicated to capturing the interviews detailed in the next section while the other two stationary cameras each captured up to one-half of the computer room. The four audio recorders were distributed throughout the room to maximally capture conversations within and between small groups. Altogether, these devices generated approximately 6 hours of data for every real-time hour of classroom activity. Files were uploaded and backed-up on a shared server, providing access generally by the end of the same day.

The fourth grade class in Study One used multiple rooms and seating arrangements over the course of the enactment. These variations required modifications to recording strategies that limited the number of groups captured and, in turn, complicated subsequent efforts to track students. In contrast, the sixth grade classes used one computer room for the duration of the study. Moreover, the room's row-seating arrangement maximized recording coverage and presented a natural structure for organizing the digital corpus. The floor plan for the sixth grade computer room is featured in Figure 3.8 with circles and squares denoting the distribution of audio and video recording.

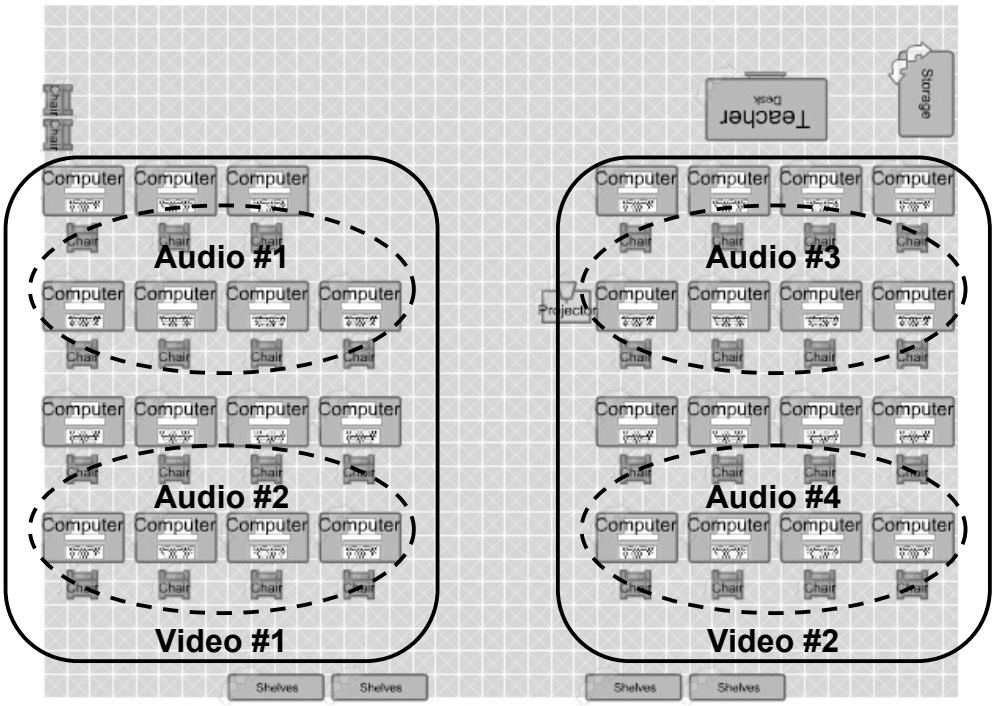


Figure 3.8 Classroom floor plan and audio-video captures in sixth grade implementation

Interviews

The researcher conducted 26 brief (less than five minutes), *in-situ* interviews with a broad cross-section of students in the sixth grade liminal transitions classroom. Who to interview and when to do so was sometimes determined on the basis of theoretically key events in the curriculum (e.g., time travel or liminal transitions) or the apparent intensity of a student's experience (e.g., an emphatic criticism of an NPC). However, in general the researcher targeted students who seemed to be enacting the curriculum in different ways (e.g., individually versus collaboratively) in order to generate maximum variation in student experiences. This process continued throughout these latter seven periods because responses were illuminative and infrequently redundant. Three students were also interviewed multiple times. These interview sequences occurred either earlier and later in a class period or across different periods.

Interviews were initiated by asking the student an open-ended question such as, "Tell me what you're doing in Taiga today," then used elaboration and clarification probes to understand student experiences with the curriculum. The immediacy with which questions about a particular event were asked enabled students to incorporate the curricular environments in their responses. Students often quoted web-pages or moved their avatars to particular areas of Taiga in order to elaborate or clarify their responses. At the same time, the public setting and the researcher's status as a classroom visitor likely shaped students' responses as well. Consideration of these and other influences reflect a theoretical assumption that interviews, like all activities, constitute a form of participation, and one that can be quite different from participation with the curriculum. Interviews represent events with interpretive challenges and not simply what the interviewee says. As one poignant example, Lee and Roth (2004) illustrated ways in which even a renowned environmental scientist might discuss both himself and his research differently in an interview context than he would in other contexts, underscoring that interviews are not an unproblematic methodology for generating data. In sum, the interviews generated in this study were considered to be as transactional as engagement with the curriculum. They are of particular interest because they present targeted opportunities to make meanings, rather than simply share them (e.g., Baker & Johnson, 1998).

Artifacts

Nearly everything that a student does in QA can be documented in electronic databases. For the purposes of this dissertation, only students' written formulations were retrieved (e.g., email, essays). In both studies, all responses to curricular tasks were

collected. Depending on how much of the curriculum a particular student completed, this could total six short essay responses associate with Quests and eight short paragraph responses associated with "textbox dialogues." Textbox dialogue refers to students' typed entries that respond to various questions embedded in ongoing curricular activities such as an NPC's comments. For the sixth grade study, students' real-time writing of chat entries and emails were also retrieved and, additionally, their paper-based field notebooks were collected. These additional sources reflect the relatively greater focus on the second study.

The array of data generated through fieldnotes, audio-video recordings, and interviews together with the artifacts collected from the QA database created an extensive corpus. Table 3.4 uses arbitrary metrics to provide a sense of the quantities of data collected. Importantly, the "opportunity cost" of defining selection parameters for the information retrieved from the QA database made it easier to simply collect the large volumes of email and chat. The quantity of emails includes the messages sent by users both before and during the enactment, while the large chat quantities represent entries from all QA users during the four-week span of the sixth grade enactment.

TABLE 3.4

Data Corpus Quantities

Data Source	*4th Grade Liminal Transitions*	*6th Grade Liminal Transitions*
Researcher fieldnotes	22 hand-written pages	32 hand-written pages
Digital audio files	~2800 minutes	~2800 minutes
Digital video files	~1400 minutes	~1400 minutes
In-situ interviews	10	26
Student digital writing submissions	146 pages	293 pages
Email	-	414 pages
Chat	-	~2000 pages
Student field notebooks	-	364 pages

Qualitative Analytical Procedures

The data corpus was examined to develop an interpretive understanding (i.e., Geertz, 2000) of liminal transitions. To this end, the analysis considers both continuous forms of data such as audio-video recordings and more discrete data sets such as curricular artifacts and assessments. These data reflect what Roth (2004, 2005) describes as the "natural protocols" of students' efforts to make sense of, and impose structure on, their experiences. These varied sources of data reflect a concurrent nested strategy for using multiple methods (Cresswell, 2002).

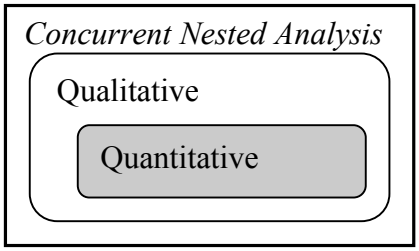


Figure 3.9 Diagram of a qualitative concurrent nested approach to multiple methods design

Given the complexity of the classroom groups and their activities considered in this study, this nested strategy affords deeper appreciation of the enacted curriculum and the individual-environment transactions realized through the events of situated action.

Over the course of the enactments, the curriculum provided students with opportunities to participate in the work of science. Situative perspectives consider participatory forms of learning through methodic analyses of observable social interactions and concrete written artifacts. However, while these data represent participation, they do not definitively prove what students have or have not learned. A key ontological assumption that guides this dissertation is that meaning is neither what is in the head nor what the head is in but rather the relations between them (Cole, 1996). Therefore, the goal of this section is to communicate a methodic process for transforming the data corpus into trustworthy descriptions, analyses, and interpretations (Lincoln & Guba, 1985). To this end, the notion of trustworthiness is briefly discussed before explaining the process of making sense of the various forms of data and piecing them back together in order to understand classroom events. These explanations focus primarily on the analyses generated as intermediate steps towards communicating the findings discussed in subsequent chapters.

Trustworthiness of Social Constructivist Qualitative Inquiry

Validity is a representation of epistemological and ontological commitments. This dissertation approaches the validity of qualitative analysis from a social constructivist perspective (Guba & Lincoln, 1990). Social constructivist views of research assume that there are always multiple plausible interpretations of an event. The goal of analysis is to develop one possible understanding of a complex phenomenon while simultaneously communicating the process through which this understanding emerges. This view of inquiry is consonant with a situative theory of learning.

Situative views assume that meaning is enacted in the learner's process of engaging her material and social environment. At the same time, the reflexive relationship between learning and how it is constructed by research implies that the same holds for the researcher's process of engaging his data. Therefore, the findings discussed in subsequent chapters fundamentally reflect the analytic process through which such data were constructed. Moreover, because meaning lies in these various processes and is not "out there" as a separate, independent property of various phenomena, there always remains an inescapable plurality of meanings to be made. Consequently, the pervasive background conditions of any event and the inherent perspectivity of human experience make the researcher's task, and tension, one of relative emphasis and not complete understanding.

A fundamental risk in interpretive research of this kind is that the researcher's understanding may be just that. This is to say that interpretations may not be applicable to other settings, may not be consistent in similar settings, may be biased, or simply fail to earn the reader's confidence. These tensions are addressed in terms of the notion of

trustworthiness (Lincoln & Guba, 1985). Trustworthiness is essential if an analytic process is to generate substantive findings; it is equally essential in the reporting of this process so findings can be appropriately evaluated by the reader. There is no finding that does not intimately relate to the analytic process of its construction. Therefore, it is the researcher's charge to convey a defensible process that establishes the credibility of the relationship of the evidence to the findings that is open for inspection so that readers are free to draw their own conclusions. The "proof" in findings is as much in the details of the researcher's effort to temper bias and build defensible interpretations as it is in the plausibility of the interpretations themselves.

Several strategies have been employed to establish the trustworthiness of this analysis. First and foremost, the analytical procedures discussed in the following sections detail the process of analysis and provide a summary description of intermediate steps involved in making meaning with the data. This accounting of the process reflects an elaborate audit trail that the researcher built from the raw materials and connects to findings. This includes source codes that accompany excerpts presented in subsequent chapters, thus connecting findings back to the data materials. Second, the researcher revisited the intermediate analyses in order to explore the progressive subjectivity of developing analyses and interpretations.

Social constructivist research assumes a reflexive relationship between a researcher's understanding of classroom activities and the inferences constructed from available data. The act of attending to and reflecting on evolving understandings and inferences by revisiting intermediate steps develops the researcher's awareness of and fairness in depicting observed events. It also works to establish the "authenticity" of

interpretations (Lincoln & Guba, 1985). This process was documented primarily by color-marking successive rounds of coding on printed documents and through revisions to logged analytical comments, thus preserving their unfolding chronology. Third, the author used negative case analysis. This involves engaging and formally discussing data that either did not support or appeared to contradict patterns emerging through data analysis. Whereas quantitative research designs coordinate and control variables to reveal causal relations, interpretive research employs negative case studies to qualify the applicability of concepts like liminal transitions by highlighting mediating conditions. The combination of these strategies underscores the researcher's effort to develop an interpretive understanding of classroom interaction in ways consistent with a social constructivist approach to qualitative inquiry. The next section provides the concrete details of this methodic process by explicating a unit of analysis and the process of making meaning of the data in terms of that unit.

Timescaling Units of Analysis

Situative views of learning focus on (curricular) events as a general unit of analyses (Lave & Wenger, 1991). In turn, events constitute learning and knowing and therefore define the fundamental unit of analysis for this dissertation. However, events can be considered in many ways (Cole, 1996). In this dissertation, Lemke's (2000) conceptualization of *timescales* refines the analytical boundaries of curricular events represented in the data corpus. Timescales refer to the rates at which social events repeat themselves. For example, a school day is organized around repetition of lessons while a semester is organized around the repetition of school days. Table 3.5 lists a range of schooling activities and the timescales along which they are typically organized.

TABLE 3.5

Timescales of School Activity (adapted from Lemke, 2000)

Recurring School Activity	*Timescale*	*Time in Relative Units*	*General Description*
Utterance	1-10	Seconds	Short monologue; in context
Exchange	$1\text{-}10^2$	Seconds to minutes	Dialogue, interpersonal relations; developing situation
Episode	10^3	~15 minutes	Thematic, functional unit; educative
Lesson	$10^3\text{-}10^4$	Hours	Curriculum genre
Lesson sequence	10^4	~2.75 hours	Macro curriculum genre
School day	10^5	Day	"Seamless day"
Unit	10^6	11.5 Days	Thematic, functional unit
Semester	10^7	4 Months	Organizational level

These activity categories and divisions of time roughly approximate patterns in the social systems they represent. In one sense, framing schooling events in terms of timescales presents a hierarchy from moment-to-moment to month-by-month activities. This framework conceptualizes the ways in which participation builds from a comment, or perhaps even a gesture, into semesters and the wider institution of schooling.

Regardless of which recurring school activity is considered to be the focal event, the chosen unit of analysis should remain situated between the shorter and longer adjacent timescales of the system under consideration. This dissertation focuses on Lemke's category of "episodes" as the focal events of liminal transitions, and considers these transitions in relation to the events operating along adjacent timescales. In the context of the curriculum then, episodes translate into the various tasks that students

engage in order to complete a missions. Following from Lemke's original framework, Table 3.6 lists the range of events associated with *The Taiga Fishkill Project* and the timescales along which they are typically organized. Importantly, the table can be linked to Table 3.5 by matching activities in terms of the timescales columns.

TABLE 3.6

Timescales of The Taiga Fishkill Project *Curriculum Activity*

Recurring Curricular Activity	*Timescale*	*Time in Relative Units*	*Curricular Description*	*Relevant Data Collected*[1]
Navigation, typed or spoken utterance	1-10	Seconds	Exploring 3D world; chat entry; spoken comment	Audio-video files, chat, emails, field notebook entries
Interactions	$1\text{-}10^2$	Seconds to minutes	Dialogue, interpersonal relations; 3D interactive sequences	Audio-video files, chat, emails, textbox dialogue entries, field notebook entries, interviews
Mission tasks	10^3	Minutes to ~1 hour	Quests; interactive goals (e.g., collecting water samples, interviewing NPCs)	Quests, textbox dialogue entries, fieldnotebook entries, interviews
Missions	10^4	~2-3 hours	Curriculum genre	Quests, textbox dialogue entries
The Taiga Fishkill Project	10^6	~12-14 days	Thematic, functional unit	Multi-level assessments

[1] Fieldnotes are omitted but apply to all timescales.

The moment-to-moment navigational movements in the QA virtual space and the spoken and typed comments that students formulate begin to organize a series of events that constitute the curricular enactment. With "mission tasks" as the focal unit, the analysis considers both the shorter-term processes that make episodes possible and the longer-term processes that constrain what is likely and appropriate during an episode. For

example, the shorter-term adjacent timescale (e.g., interactions) represents the processes through which the focal unit (e.g., mission tasks) are made possible, while the longer-term timescale (e.g., Missions) shapes what is probable within these possibilities. The remainder of this section details specific analytical procedures by "timescaling" the analysis of data. A timescales framework expands the concurrent nested approach to multiple methods research discussed earlier by nesting data in terms of the event categories they constitute. Figure 3.10 illustrates this organization.

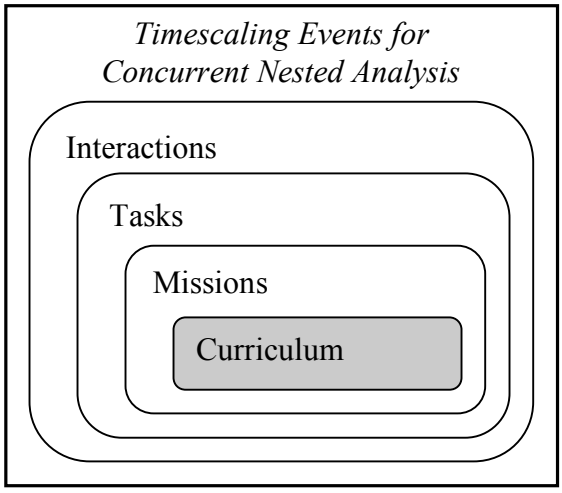


Figure 3.10 Diagram of timescaling concurrent nested analysis

Shading denotes events represented with quantitative data, paralleling the general strategy represented in Figure 3.9.

In following this analytic organization via timescales, analyses began from the shorter-timescale interactions that, in turn, shape focal-timescale mission tasks then concludes with the analyses of longer-timescale Missions. At the same time, there is no absolute origin to an interpretive analysis, but an essential circularity (Packer & Addison, 1989). As the following sections detail, each cycle of analysis fostered progressive subjectivity, but this progression was tempered by self-reflexive reviews of earlier cycles.

In this sense, the analytical procedure developed a holistic picture that was, in turn, brought to bear on the component analyses from which it emerged. Finally, as discussed earlier, these analyses primarily focused on the sixth grade enactment but additionally included the fourth grade enactment when explicitly stated.

Shorter-Timescale Interactions

In order to build a comprehensive review of written materials, printed copies of all materials were reviewed chronologically by form. Anything that appeared interesting was marked, and notes about why it was interesting were written in the margins. As this process continued, certain kinds of notes repeated while various others only occurred a small number of times. Recurring notes were formulated into themes or categories before being collected and, as necessary, synthesized or refined to reconcile overlap. This initial process is detailed for each form of data in the following sections.

Data reduction. As mentioned earlier, it was easier to retrieve larger volumes of data from the QA database than to specify specific research parameters. For example, the large volume of email identified in Table 3.4 diminished significantly by simply skipping all emails that predated the sixth grade enactment. Similarly, because chat was organized in terms of the virtual geography of QA, these logs could also be reduced to the specific areas where the curriculum took place by simply skipping unrelated areas. At the same time, it was important to maintain the entire chat corpus because groups of students sometimes moved to areas unrelated to the curriculum, and these unpredictable patterns could often be identified. Ultimately, the email log was reduced by at least three-quarters and the chat logs were reduced by at least one-half.

Chat. Chat logs were printed by day and reviewed in week-long chunks, beginning on Mondays. Because the majority of students did not log on to QA during weekends, this chunking strategy reflected recurring divisions in the generation of the data itself. Many individual entries and all sequences of topical entries were flagged and impressionistic comments written in the margins. Emergent themes across these notes were collected after the first 7-day period and successively synthesized with themes in subsequent weeks. In general, chat was a mixture of independent entries of various sorts punctuated, at times, by brief exchanges of between two and 10 entries. Themes and brief descriptions are provided in Table F1 in Appendix F. Importantly, these themes directly reflect the initial cycles of analysis discussed here, but they also reflect a subsequent review of the data with these themes. This review of data is discussed further in the next section. A limitation in this data set is that beyond an entry's author and those who responded, it remained unclear who might have read chat regularly and who did not.

Email. Email logs were printed chronologically by student and were reviewed in that order. Most students did not use the QA email function during the curriculum and those who did typically used it for non-curricular topics. Given the private and targeted nature of email, however, students more often responded to one another, creating email "threads" when they did use this function. Non-irrelevant emails were immediately compiled in an eight-page document and organized into categories (See Table F2 in Appendix F) that closely resembled a subset of themes in the much larger chat logs. Importantly, since the very use of email was not a representative aspect of the sixth grade enactment, the medium of email was ultimately backgrounded and interactions it

facilitated were foregrounded. In this way, meaning making was prioritized over the medium through which it occurred.

Audio-video corpus. Analyses began with the creation of content logs (e.g., Jordan & Henderson, 1995) for each of four audio files for each class period. As discussed in the data collection section and detailed in Figure 3.8, each audio file captured two rows of three to four students each. The researcher made notes about the utterances and exchanges among these groups, including the time when they occurred. These notes were organized in a spreadsheet with one column per group across 14 periods, generating roughly 700 log entries. The content log structure and sample content log entries are provided in Table G1 in Appendix G. In this way, content logs described comments and discussions that the researcher could quickly retrieve and selectively transcribe.

Field notebooks. Students' field notebooks were reviewed and impressionistic comments added in the margins. However, notes were often cryptic and handwriting was sometimes difficult to read. The only reasonable conclusions that could be drawn from this review related to what sections of the notebook were used. Table 3.7 details the total number of students who used notebook pages corresponding to each mission relative to the number of students who completed the mission.

TABLE 3.7

Number of Sixth Grade Students Who Completed Missions and Used Field Notebooks

Mission	*No. of students using the corresponding notebook section*	*No. of students completing mission*
1	24	26
2	19	26
3	11	25
4	8	17

Nearly all students used the field notebook at the outset, while only half of those who reached the final Mission did so. At the same time, while each mission section of the notebook included pages for notes and others for preparing Quest responses, less than one-quarter of the students used any of the Quest-related pages.

As this section has detailed, the analytical process began with discrete cycles of analysis with a subset of relatively brief written forms of data and a moment-by-moment consideration of the complete audio-video corpus. Many of these data were simultaneously generated and the work of analysis necessarily began by breaking down events into these functional structures. In turn, to make the large amount of data more useful to the broader analysis of Mission tasks, they were organized into themes and categories.

Focal-Timescale Mission Tasks

At the next timescaled level of events, analysis considered data generated along the recurring cycles of mission tasks. This primarily included more elaborate writing submissions. These formulations were generally more elaborate, were deeply relevant to the curriculum, and directly drew upon a range of shorter-timescale interactions. At the same time, these submissions comprised mission goals and ideally drew upon the targeted curricular content. In this way, written submissions associated with mission tasks constitute the intersection of what the curriculum design intended to happen and what emerged through the curricular enactment. For these reasons, they were carefully considered task by task. Meanwhile, a second goal at this level was to use the audio-video content logs to methodically construct a chronology of events and artifacts in order

to locate particularly meaningful sequences of events across data forms. Doing so also made the data useable for subsequent analysis of students' trajectories of participation.

Task submissions. All Quests and textbox dialogue entries were printed and reviewed for the fourth grade and sixth grades classes. Relative to the more interactional forms of written materials, these submissions were entirely focused on curricular experiences, were much longer, and were often elaborate. The specific quantities of materials reviewed are detailed in Table 3.8.

TABLE 3.8

Quantities of Written Submissions

Data Source	*4th Grade Liminal Transitions*	*6th Grade Liminal Transitions*
Quest 2	46 pages	73 pages
Quest 2.5A (Diagrams)	12 pages	30 pages
Quest 2.5B (Proposal)	10 pages	27 pages
Quest 3	7 pages	49 pages
Textbox Dialogue 3.5A (Filters)	6 pages	12 pages
Textbox Dialogue 3.5B (Stream)	3 pages	10 pages
Quest 4	5 pages	28 pages

While these page counts are far less than those for email and chat, the researcher generated analytical categories for each task submission in the same manner described above. The more detailed analysis reflects the richness of the submissions and relative complexity of the formulations. Categories for the first three submissions – Quests 2,

2.5A, and 2.5B – as well as illustrative student examples are provided in Table H1 through H3 in Appendix H. Also, Quest 1 and a subsequent textbox dialogue submission in which students blamed one of the three groups were also reviewed in order to determine the distribution of hypotheses and blame within each class. And finally, the relatively larger page counts for Quest 2 reflect a more rigorous review process that generated a correspondingly greater number of revisions.

Expanding the content log. A complementary analytical procedure for understanding mission tasks in the sixth grade class was to selectively synchronize the various descriptions in the audio-video content logs with the range of artifacts collected. For Quests, the researcher noted in the content log who submitted each quest, when they submitted it, and whether it was accepted or needed revision. With respect to chat and email, the goal was not to include all data or to only include clearly relevant data, but rather to include the likely relevant data (including negative cases). Further, probable relevance was considered in terms of what was done with language via a particular form of data and not how representative the particular form was in the broader scheme of the enactment. (A sample of probably relevant chat and email entries for one day are presented in Table G1 in Appendix G.) This process was greatly facilitated by preserving the temporal order of shorter-timescale interactional forms. In other words, the researcher could linearly page through chat logs and compiled emails while simultaneously scrolling through the content log spreadsheet, appending new entries to both papers and spreadsheet cells.

This synthesizing task accomplished multiple goals along the way, resulting in a rigorous study of trajectories of participation. First, as was alluded to in the chat analysis,

this synthesis provided an activity through which to re-examine interactional data with the concomitant themes derived from the data (see Appendix F). Second, it created a reflexive activity through which the researcher could monitor and record his progressive subjectivity. That is, by reviewing interactional data, the researcher's previous notes could be challenged, rejected, refined, or affirmed, and any revisions were documented with a different colored pen. At the same time, the review began to refine the interpretive relevance of data given the categories generated in light of the reviews of the mission task materials. Lastly, compiling an array of moment-to-moment interactions illuminates the enactment of mission tasks and begins to afford a kind chronological analysis (Yin, 2003).

This section has detailed a second level of event-based analysis that was conducted with written submissions and interactional data relevant to mission tasks. In summary, more elaborate, task-related, written submissions were reviewed, annotated, and categorized. These characterizations were then enlisted to review the interactional data and selectively append the content log with probably relevant details. This elaboration provides a chronology of tasks that included episodes of observable interaction from which these mission tasks emerged.

Longer-Timescale Missions

The final level of analysis for event-based data considered the overarching Mission structures detailed in Table 3.2 and students' trajectories of participation along these pathways.

Sequencing written submissions. Mission task submissions (specifically the final versions approved by the respective classroom teacher) were grouped by student and

reviewed chronologically by the researcher. Two sequences of submissions were arranged for each student. The earlier sequence considered Quests 2, 2.5A, and 2.5B and the later sequence considered Quest 3, textbox dialogues associated with Mission 3.5, and Quest 4. Each sequence was examined with respect to the curriculum's target standards and concepts. This theory-based analysis considered both the presumed patterns across one student's submissions and across all students for a sequence. (Appendix I presents one student's later sequence with codes.) The writing prompts for each of these tasks directly reflected targeted standards and submissions, in turn, reflected the prompts, therefore applying these codes was, in most cases, clear and straightforward. Characterizing trends or themes across these coded submissions, however, proved to be more challenging. The variety across student submissions across tasks afforded only the basic categories of consistent, inconsistent, or developing appreciation for each of the standards.

Interviews. The researcher generally reviewed interviews as soon as possible after class periods, but sometimes up to one week later. 13 of 26 interviews were closely transcribed while the remaining 13 others were only paraphrased, reflecting the relative richness of the conversations. Transcripts were coded with respect to missions and mission tasks.

Clustering with content logs. Previous cycles of analysis had already layered content logs with timescaled data. In order to consolidate all relevant information, field notes and interview descriptions were also appended. The complete spreadsheet was then printed as a banner and reviewed by day. Data were coded within and across days in order to build a holistic picture of the enactment. Data were also clustered when they

defined sequences of interaction, and this clustering began to define cases of individual students' trajectories of participation. Log entries sometimes directed the researcher back to audio files in order to re-examine relevant interactions and episodes. The timestamped interactions associated with approximately 75 log entries were transcribed in order to provide more depth to the entry descriptions. However, because student discourse usually interleaved ongoing game play, each entry marked only brief moments. Therefore, transcripts were typically between five and 15 lines each. These reviews of data refined emerging patterns of written, spoken, and computer-mediated interactions.

These patterns serve as the researcher's primary acts of meaning-making. From these acts emerge interpretations of students' language-in-use, which consider the ways that students and liminal transitions transformed participation with the curriculum. As is detailed further below, transcripts were considered in terms of the form and function of written and spoken formulations as well as the social actions they achieved within the social contexts in which they were embedded (Gee, 2005a).

Approach to analysis of language-in-use

This study draws on discourse analytic principles (Gumperz, 1982; Halliday, 1978; Wortham, 2006) and, in particular, Gee's (2005b) approach to analyzing discourse in order to address the first two research questions of this study. Broadly speaking, discourse analysis studies patterns in language use as constitutive of semiotic webs of meaning beyond basic units such as clauses or sentences. Understanding the ways that student participation shapes and is shaped by liminal transitions in Taiga requires an appreciation of the emergent communicative practices and roles that students enact through language-in-use via the curricular experience. The situated meanings that emerge

through this participation are mutually constituted—organized, in part, by the structures of participation and, in part, by the contexts of language-in-use (Gee, 2005a; Goodwin, 2000). These two aspects of language—structure and context—reflect a view of discourse as a social system organized to both communicate and build meanings (Gee, 2004a). Two analytical tasks follow from this view: understanding possibilities and potentials of language-in-use.

Discourse must be understood in terms of the possible and probable meanings of an utterance. The possible meanings of language can be understood in terms of traditional linguistic forms and structures (Gee, 2005a) and the set of context-independent functions or meanings that a form suggests (Gee, 2004a). The probable meanings of language can be understood in terms of the set of contextualized meanings that an utterance assumes when organized to fit particular patterns of language use. Therefore, any type of utterance has a set of potential meanings that require inferences about the situated meaning embedded in context (Gee, 2005a).

As ways of talking develop into increasingly complex and nuanced relations, potential functional meanings become increasingly dependent on a person's competence with not only context, but also points of view and cultures. In this way, discourse analysis aims to relate language use to the patterned social interactions that organize and are organized by shared understandings and practices. As patterns come to increasingly shape the social and material environment, they, in effect, arrange their rediscovery across time and space, building meanings that, while still local, transcend the interaction that (re)creates them (Cole, 1996; Lave & Wenger, 1991; Wenger, 1998). Increasingly patterned participation with shared ways of being and knowing cultivate "communities of

practice" (Wenger, 1998) with patterned ways of talking that Gee terms capital-D discourse (hereafter Discourse).

A Discourse represents ways of being in the world, or the ways of being a "kind of person" (Gee, 2004a, 2005a). Any given Discourse encompasses cultural models about the world and situated languages for talking about it, which, together, develop as ways of interpreting one's experience. Cultural models represent taken-for-granted stories about shared but constantly renegotiated patterns of meaning. Social languages are a lens for talking about and making sense of situations. Cultural models and social languages combine in small-d discourses—empirically observable social interactions—to build meanings that are "customized in, to, and for context, used always against a rich store of Discourse knowledges that are themselves 'activated' in, for, and by contexts […]" (Gee, 2005a, p. 78).

In this view, learning represents a trajectory of attunement to a Discourse or Discourses. As an individual attunes to certain ways of being and their attendant values, learning is reflected in increasing participation, in terms of both doing and being. However, more than the competencies constituted through words, learning is the process of knowing—of seeing, doing, and being in certain ways (Packer & Goicoechea, 2000). Learning a Discourse is a way of constituting and experiencing the world as a certain kind of person in activities and through experience. Learning, then, is the transformation of participation that increasingly resembles particular Discourses.

This approach to discourse analysis attempts to make learning understandable by mapping trajectories of participation across the multiple layers of context to which language-in-use, and the orientations it suggests, relate. "Learning is … more basically a

process of coming to be, of forging identities in activity in the world" (Lave, 1991, p. 143). In this sense, the analysis presented here aims to understand the content of participation (i.e., text or utterance) as functions of the systems of activity through which they emerged such that both the multi-layered mechanics of language and the fluid architecture of interaction represent tools for making meanings in terms of communities that transcend the event itself (Gee, 2005a).

Quantitative Analytical Procedures

Nested within the qualitative inquiry, a multi-level assessment strategy aimed to quantify student transitions into a range of discretely framed constructed-response and multiple-choice items. These data provide information at the level of the curriculum and afford a general understanding of the ways students' participation can transition into typical schooling accountability practices. Meanwhile, a quasi-experimental design considered the relative influence of two different transitional strategies. For both purposes, assessments were scored and analyzed. First, two raters scored all constructed responses on the curriculum-oriented, proximal-level performance assessment after attaining inter-rater reliability. In both studies, pre-post means for each assessment were compared using a paired-samples t-test. Meanwhile, comparisons between the 6^{th} grade conditions in the quasi-experimental study analyzed means for each assessment using repeated measures analysis of variance. At the same time, ongoing debates about statistical significance testing (e.g., Harlow, Mulaik, and Steiger, 1997) and new perspectives on the interpretation of effect sizes (e.g., Thompson, 2006) suggest that it may be useful to generate both statistics regardless of statistical significance. This is a particularly useful strategy when treatments presumably generate a cumulative effect

over time (Abelson, 1985). Therefore, effect sizes were computed using Cohen's *d* with original standard deviations.

In summary, this chapter has provided information about methods used to study the general consequences of learning within a situative theoretical framework. It provided specific details about the participants and an overview of the game-based curriculum they engaged. Concrete design strategies were explicated, translating earlier theoretical discussions about liminality, prolepsis, and polycontextuality into viable curricular practices. The chapter also detailed the multi-level assessment measures used to generate data about learning as well as the quasi-experimental comparison of liminal transitions to a more conventional formative assessment strategy. These quantitative analyses are nested within a broader qualitative inquiry of an extensive collection of data. This data reflect moment-to-moment interactions and longer-term activities to which they relate. The overall purpose of this inquiry is to increase and deepen understanding of the general consequences of learning in terms of doing science and being scientific (Wenger, 1998). The analytical procedures for accomplishing this goal were detailed in terms of an event-based analysis. This unit of analysis was further organized in terms of Lemke's (2000) notion of timescales. Cycles of timescaled analyses were detailed, and efforts to establish the trustworthiness of the process were explicated. Based on this methodic consideration, the following three chapters report findings in relation to the three research questions guiding this dissertation.

CHAPTER 4

QUALITATIVE FINDINGS

This chapter reports the findings of a case study analysis of liminal transitions in an elementary-level science curriculum. One fourth grade and one sixth grade class engaged an ecology problem set within a multi-user virtual environment called Quest Atlantis (QA). These enactments generated a digital corpus of classroom audio-video recordings as well as a range of ethnographic data including fieldnotes, student interviews, and a database of written artifacts. Lastly, it incorporated a series of pre-post assessments. This dissertation addressed both of these enactments with three aims: to understand the ways in which liminal transitions support learning and reveal knowing, to inform design principles that inform participation with immersive game-based curricula, and to compare the consequences of learning related to liminal transitions with those related to conventional formative assessment activities. In pursuing the first of these goals, this chapter reports the researcher's findings in order to develop a deeper understanding of liminal transitions. Through the methodic analysis of a curricular chronology, it specifically reports on the enactment of liminal transitions within students' broader trajectories of participation with *The Taiga Fishkill Project* curriculum

General Descriptions of Curricular Enactments

The section provides whole class chronologies of curricular enactments including both designed and emergent forms of participation. The design of the curriculum and liminal transitions aimed to support certain activities and practices, but these designs are

inevitably enacted uniquely in each classroom and often in unanticipated ways. By describing different classes and the ways they engaged the same curriculum, this section offers a general representation of weeks-long events, a sense for possible variations, and, most importantly, a grounding on which more particular descriptions and analyses build.

Fourth Grade Qualitative Description

Seventeen fourth grade students enacted the curriculum across fourteen 50-minute class periods over four weeks' time. These students were all labeled as gifted and, based on classroom observations preceding the enactment, all seventeen appeared to be curious about and engaged in classroom discussions and activities. Against this backdrop, their teacher Becky (all names are pseudonyms) was nevertheless struck by her students' engagement and frequently emphasized to the research team that she found their enthusiasm remarkable. In fact, Becky asked that research reports underscore her students' heightened interest relative to all other curricular units they completed during their previous seventeen school weeks together. She explained that students often arrived at school in the morning eager to recount what they had accomplished at home and/or to discuss what they planned to do during *The Taiga Fishkill Project* curriculum that day. Moreover, chat logs revealed that six students periodically logged on to QA at night or over weekends in order to work on their Missions; five other students did the same at least once over the four-week time period; one even logged on while sick at home in order to work with her group. These teacher's impressions and illustrative examples underscore an uncommon eagerness on the students' part that persisted across all fourteen class periods. While this is an important aspect of the enactment, this theme is omitted

from the remainder of the overview in order to focus more closely on the ways in which the class and the game-based unit together enacted a curriculum.

In the first period of the curriculum, Becky asked students to volunteer to read paragraphs from an introductory letter from the Ranger of the virtual Taiga National Park (hereafter Taiga). Pauses between readers' turns were punctuated with speculations about Taiga and questions about the letter. Other students' responses to these speculations and questions generated brief discussions that Becky sometimes facilitated with guiding questions. One student asked about the meaning of the word "indigenous" and, after several students agreed that they did not know it either, Becky defined the term. Upon finishing the letter, small groups used the letter to discuss Taiga's fish population problem as well as both relevant information that the ranger's letter provided and essential information that it omitted. Becky reconvened the whole class in the closing minutes of the period in order to debrief their group conversations. Students shared ideas about possible causes of the fish decline that they might investigate, such as litter, engine exhaust, and trees. Both the small group and whole class debriefing conversations suggested that students were wrestling with the open-endedness of the problem.

Across six periods during the next seven school days, the class worked entirely in computer labs, each at her own computer. Students worked individually for the majority of these periods with the exception of one team of three. These two boys and one girl discussed the scenario and helped one another keep an even pace. All students navigated the virtual landscape and interacted with non-player characters (NPCs) for the majority of each period but only inconsistently engaged one another in discussions as this group of three did. Becky typically used the last three to five minutes of each period for whole

class debriefings about class-wide progress towards solving the fish problem. As with the discussions observed before the enactment, a range of students participated but Becky typically selected one or two as well. Students' observations in the first few periods noted areas of green and brown river water, and several conducted fish counts; but by the latter of these six periods they also connected these observations to the perspectives that NPCs revealed. For example, what had been "brown water" was often described as "sediment near the loggers", which one NPC had suggested.

In addition to what students saw in the QA world and read through interactive dialogues, they also commented on the different ways that they experienced these textual and perceptual interactions. For example, one student observed that during interactions with NPCs, "you can be rude if you want to", reflecting the multiple response options available to players during dialogues and the ensuing consequences in NPC replies. Also, students consistently used first-person pronouns in the descriptions they offered to one another and in written submissions, taking the perspective of their QA avatars. For example, when swimming through the river, one student commented "Oh no, I got my dress wet!" It is through explorations and discussions of these virtual journeys that students progressed through Mission 1 and into Mission 2, as described in chapter 3.

The initial seven class periods described above related to the first and second of four main Taiga Missions. The diversity of submitted hypotheses (Quest 1) suggested that students recognized one or more issues within the Taiga community. However, the fish problem remained ambiguous to the class as a whole. As students proceeded to their second Mission, they collected water samples and generated data about several water quality indicators (e.g., pH and turbidity). Early Quest 2 submissions showed that, while

students interpreted these data , they struggled to formulate explanations in terms of the fish problem or to connect the data to specific impacts to which the various groups might contribute (Quest 2). While only five students had submitted Quest 2, Becky used the eighth class period to interleave the curriculum with a one-period classroom-based activity.

Becky's teacher-led discussion addressed water quality data and its relation to Taiga. For the five students who submitted Quest 2 already, this discussion represented a just-in-time lecture. Using an overhead projector, Becky sketched the Y-shaped river on a transparency and included data values, each beside its respective collection site (note that the 2D Taiga map in Figure 3.2 identified these water collection sites using circled letters). Students contributed their interpretations of the data and responded to Becky's guiding questions. This interleaving activity revealed a useful insight about the curriculum that will be discussed in terms of the revisions made for the second study.

In the final six periods of the fourth grade class's curricular enactment, all students continued their second Mission. The teacher accepted thirteen students' submitted responses for the second Quest, and planned absences or illnesses delayed the remaining students. These submissions generally included detailed explanations of issues underlying the fish problem, incorporating processes like erosion to connect group activities with the water quality indicator data. Given that the Quest had to be accepted, students averaged more than two revision cycles (more than three submissions) while five students engaged in five cycles (six submissions). This revision process was reflected in the more elaborate final submissions relative to other Quests.

With their second Quest approved, ten students completed the first of two liminal transitions described earlier in Chapter 3 (Mission 2.5) by explaining diagrams (Quest 2.5A) and evaluating a farm expansion proposal from the indigenous farming community to annex additional land (Quests 2.5B). As the 14-period enactment neared completion, seven students spent from one to four periods time-traveling to the future Taiga scenarios associated with the later Missions detailed in Chapter 3. Time traveling students announced that they were in a different Taiga, quickly drawing small groups of students around their computer screens and convening discussions about changes they saw in the virtual environment. After further exploration and interviews with NPCs, students speculated about why simply blaming one group, as they had been required to do in Mission 2, failed. Several students critiqued the strategy to single out one group; all agreed that one group alone was clearly not responsible, leading some to propose a more balanced resolution and others to blame another group. All seven of these students also completed Missions 3.5 (i.e., the second liminal transition mentioned in chapter 3). Through collaboration, pairs of students coordinated entry into a Taiga cave and met with the Atlantian Council member, Lan; however, only the group of three students who had collaborated throughout the curriculum continued to work together on the problems posed once inside. Lastly, five students also time traveled again to a healthy Taiga in the distant future. They investigated the park and engaged the groups once more in order to evaluate one possible solution that had effectively balanced the social and ecological issues underlying the problem.

Analysis of Study One for Study Two Curricular Revision

While the end of the fourth grade enactment overlapped with the beginning of Study Two, it was still possible to modestly revise the curriculum in order to better illuminate the intentions of this dissertation. In general, ongoing observations and cursory analyses of fieldnotes and student writing submissions suggested that the fourth grade class meaningfully engaged the liminal transition activities and the broader curriculum, though only very few completed the latter liminal transition before the implementation ended. However, the classroom activity that the teacher interleaved on the eighth period revealed a valuable opportunity to learn about reading graphs scientifically. In reviewing the curriculum, the major tasks of Mission 2 provided opportunities to interpret data tables in relation to water quality indicators at a specific collection site, but not to interpret indicators across various sites in relation to the river. Becky's classroom period provided students with an opportunity to simultaneously connect (a) data about water quality indicators with (b) each site's contiguous group, and then (c) to appreciate these connections relative to the overall pathway of the river. Moreover, this discussion leveraged the ongoing relations between learners and their material and informational resources—in this case specific relations between Taiga's virtual landscape and the thirteen NPCs featured in Mission 1 with the water samples collected and the data generated from these samples in Mission 2. While the fourth grade students had opportunities to learn about "reading" tables in Mission 2, Becky's classroom activity supported further opportunities to similarly "read" Taiga's ecological systems in terms of these tables.

These conclusions about Becky's classroom session were also supported by reviews of students' Quest 2 submissions preceding the discussion. Two contrasting submitted responses illustrate isolated and contradictory interpretations. Excerpt 4.1 is from the accepted revision submitted by a fast-paced student the weekend before the classroom discussion. In it, he evaluates data from a water sample taken below the confluence of the rivers. Importantly, he attributes the unhealthy data to bleeding fish released by the sport-fishing outfit—K-Fly Fishing. (Aside: the use of courier font in excerpts denotes students' type-written responses (e.g., Quests or chat) while continued use of times-new roman font denotes spoken responses (i.e., interviews or peer conversations).)

Excerpt 4.1

> [...] By the K-Fly Fishing, the only good indicator was the pH of the water. All the others were too high or too low. It is probably caused by when the K-Fly release the fish with the hook still in them and the blood spreads. The loggers and the [farming community] had the best indicators because almost everything was perfect [Jason, P-Q2A2, 01/20/07]

This student's evaluation of the data suggests only a site-specific interpretation of the water quality issues (i.e., bleeding fish) without consideration of the systemic relations that underlie the water quality indicator data (e.g., turbid water flows from site B to pollute site C). It is unclear why this quest was accepted, because similar submissions were later required to be revised. Further, the formulation is not representative of accepted submissions in general. At the same time, it is important in this instance because it underscores why Becky prepared her interleaved discussion. In other words, it is precisely these omitted relations that Becky targeted in the subsequent classroom

activities. In contrast to this submission, excerpt 4.2 derives from a different student's initial Quest 2 response, likewise submitted before the classroom activity.

Excerpt 4.2

> The water gets dirtier when two rivers met because site C was the worst water and its right where two rivers met. It's cleaner when the site is by one river that mets. The data helps because if the site is by a group and the water's dirty then that group is causing the problem. Different groups of people are causing different indicator values. [Randal, P-Q2R1, 01/19/07]

This excerpt shows that the student interpreted the downstream data (Site C, near the sport-fishing outfit), partially in terms of the flow of the river and the accumulation of pollution. However, his concluding logic is that dirty water collected from sites near different groups is, in fact, caused by those same groups. This conclusion seems to contradict the earlier part of his submission. Both of these students' submissions include quite literal readings of the data tables, but less so in terms of the broader ecological context of the Taiga fish problem that the tables aim to inform. While excerpt 4.2 remains ambiguous, both examples suggest that the Becky's classroom discussion was, in fact, a just-in-time lecture.

Building on this discussion, the sixth grade implementations incorporated an additional worksheet in students' Field Notebooks. The new page is presented in Figure 4.1 with three overlaying tables. Each table provides space for water quality indicator data and is contrasted with Becky's overhead image.

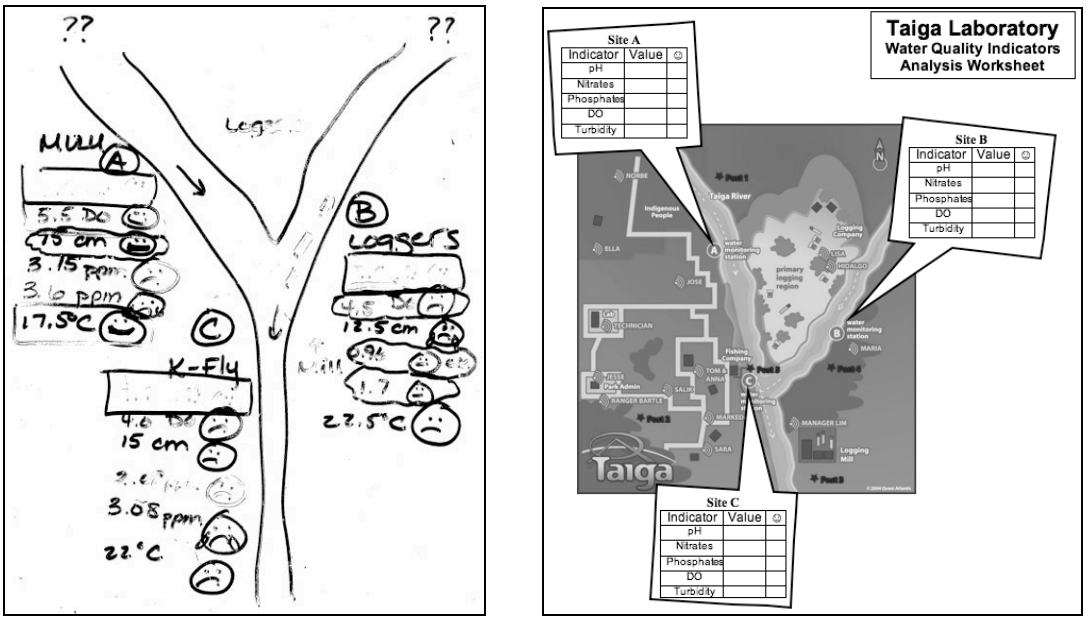


Figure 4.1 Study 1 overhead projector image of Taiga river and subsequent water quality analysis worksheet included in Study 2 Taiga Field Notebook

In this way, the worksheet served as a scaffold for students to reason with evidence by specifically pairing the data tables with the locations of the collection sites.

The opportunities that this additional worksheet arranged represent an important refinement for more closely approaching the theoretical intentions of this study. Both liminal transitions described in the curriculum follow Quest 2, which asks students to interpret the fish population problem using scientific data and the systemic relations about sites along the river that this data reveals. It is precisely these interpretations that are incorporated in an activity associated with a subsequent liminal transition. However, students must first have had opportunities to make meaning with the curricular practices in terms of curricular context. In other words, without these preceding opportunities, there is no relevant curricular practice to mediate a transition; there would be nothing to transition from and no relevant past to mediate, at least not in relation to a trajectory of participation with the curriculum.

The necessary opportunities to engage the tools and symbols of science in a meaningful situation such as Taiga are what Gee (2003b) has loosely characterized as "playing the game." In this case, the Study One curriculum provided situations through which students could learn to make sense of or "read" ecological data tables, and it obviously leveraged a rich and immersive scenario to do so. Meanwhile, the curriculum did not similarly engage students in reading these tables ecologically—in terms of the relations among and between organisms and habitats. That is, while Quest 2 indeed asks students to read the data table with respect to Taiga, and therein play the game of science, the broader curriculum did not provide an opportunity for students to learn how to do so. To be clear, the worksheet alone did not provide such an opportunity either, but it did situate the data in a geographical location. Beyond this relatively modest design change of important theoretical consequence, the first study provided an illustrative enactment to compare with the sixth grade enactment that is now described in detail.

Sixth Grade Study Qualitative Description

Because several teachers at this school had used QA over the past five years, most sixth grade students were at least somewhat familiar with the virtual environment and the elaborate QA backstory. Email logs showed that three students still continued to participate, some quite regularly. Moreover, the sixth grade science teacher had implemented *The Taiga Fishkill Project* during each of the past two school years. Against this backdrop, two sixth grade classes enacted the curriculum during fourteen class periods over four school weeks.

In the first period, the research team introduced themselves and briefly overviewed QA for the class, including a short video about the myth of Atlantis. By a

show of hands, at least three-quarters of the class acknowledged that they had seen it previously. The teacher, Jack, then selected students to read the Park Ranger's introductory letter. He also presented the class with relevant questions between students' turns at reading, such as the meaning of the word "indigenous". While neither Becky's fourth graders not Jack's sixth graders were familiar with this term, the different ways in which it became a topic of classroom conversation reflect general patterns in each class. A student posed the question in Becky's class, and several students responded before she offered any answers herself, whereas Jack asked the sixth graders this question himself. In general, whole-class conversations were student-centered and interactive in the fourth grade class and teacher-centered in the sixth grade class. In fact, the general pattern in Jack's introduction as well as in four subsequent whole-class discussions invariably resembled the common initiate-respond-evaluate (IRE) sequence of classroom interaction (cf. Mehan, 1979). That is, Jack posed an initial question, a student volunteered a response or was selected to do so, and then Jack evaluated the response. These comparisons between the classes illustrate one of the many inevitable variations across implementations and between teachers, one that may reflect the dramatic differences in peer and whole-class discussion across implementations.

In any event, after reading the introductory letter, small groups interrogated the contents of the letter in order to comment on the nature of the problem, what was known, and what was not. These discussions suggested that students understood the Taiga problem. Moreover, some groups went beyond the stated goals, sharing ideas about what the causes of the problem might be, for example.

The remaining thirteen class periods took place primarily in a computer lab. On four occasions early in the enactment, Jack led brief whole-class discussions in his classroom before moving down the hall to the computers. The topics of these briefings previewed some of the central themes of the first and second Missions and reviewed other more familiar themes. Meanwhile, in the computer lab Jack primarily engaged students through brief written reviews of students' Quest submissions and, at times, through guiding comments via chat, such as "don't forget to record what each person [NPC] says". Therefore, beyond Jack's whole-class discussions, computer lab activities primarily centered on student-computer interactions, or at times, on conversations between students seated near each other. In this sense, the curriculum was enacted less by a whole class collectivity and more by several informal groups of neighboring students and, additionally, by twelve individual students who rarely spoke at all.

In conversations and written submissions, all students consistently relayed their virtual experiences from a first person perspective and nearly all consistently appeared to be engaged with Taiga. In fact, the lab was often remarkably quiet with mouse-clicks and keyboard strokes being the only sounds. At other times, small groups discussed what they encountered and read. Less frequently still, groups co-mingled to share insights or comment on one another's discussions or debates.

Students' Quest 1 submissions revealed a variety of initial hypotheses related either to the loggers or the combination of all three groups together. After analyzing water quality indicator data, students' Quest 2 submissions had resolved the problem into key aspects of group activities, some in terms of the systemic relations across all three collection sites but others only in terms of each site in isolation. Nearly all students'

initial hypotheses focused on the loggers, either in part or entirely; again after Quest 2, nearly two-thirds of the class advised Ranger Bartle to blame the logging company before beginning Mission 2.5. Most students completed the mission without discussing the Quests. At the same time, while Jack focused his attention during class periods on reviewing and approving students' Quest submissions, his did engage several students directly around the second Quest, specifically using the diagrams of the logging, fishing, and farming activities to explain erosion and eutrophication to two students whose interpretations of the diagrams did not reflect these processes.

Several students began Mission 3 and traveled to a future Taiga on the eighth period of the enactment. Time travelers often commented to other students as they explored a new scenario in which Taiga continued to struggle with the fish population problem in the future, generating many of the infrequent discussions between students. Though to a relatively lesser degree, this was the case even for students who worked alone. Moreover, time travel prompted many of those who remained in the "present day" Taiga to express both impatience about their current tasks and determination to travel to the future.

By the final period of the implementation, all students had time traveled, completing both Missions 3 and 3.5, and twelve more students had traveled to a distant future and completed Mission 4. These activities largely occurred without discussion. To be clear, many students offered brief comments in relation to Mission activities, but these were typically isolated utterances or brief interactions that infrequently cohered into discussions. Even the student pair discussions that were explicitly requested of students

for Mission 3.5 were a rare exception in Study Two. In this sense, the enactment was akin to multiple parallel enactments rather than one collective enactment as Becky's had been.

Transforming Trajectories of Participation to Support and Understand Learning

Reflecting the situative perspective informing this study, analyses of learning and knowing focus on ongoing activities that remain open to and, in part, contingent upon unfolding situations (i.e., knowing emerges in interaction). Therefore this section develops a deeper understanding of the ways that liminal transitions were useful for supporting and understanding students' trajectories of participation in the game-based Taiga curriculum. This understanding derives primarily from the sixth grade enactment in which the majority of students completed the curriculum. The first section overviews ways in which liminal transitions were enacted in classroom settings. It also examines cases that exemplify the theoretical intentions of the design together with others that illuminate its theoretical tensions. The second section then considers the ways in which liminal transitions were useful for understanding student participation.

Liminal Transitions for Supporting Learning

This section focuses specifically on the ways in which liminal transitions provided mediating opportunities to reify the rich curricular context of Taiga. The first of these opportunities arrives with the inscriptions and farming proposal in Mission 2.5. The second is the altogether different context presented to students in Mission 3.5. Students' participation with these missions included computer-mediated interactions such as chat and email and some face-to-face interaction; it also included written artifacts associated with mission tasks. This section

discusses representative characterizations of class-wide learning in terms of mission tasks and feedback, drawing on the analyses reported in Chapter Three.

Mission Tasks: Quests

Liminal transitions each featured two mission tasks. In the first, NPC Jesse solicits students' help with two of his own Quests while they are working on their own. The first of these transitions presented inscriptions in the form of scientists' hand-written diagrams (Quest 2.5A) and a proposal from the indigenous farming community (Quest 2.5B). Both provided students with opportunities to reify the narrative they engaged across their NPC interviews. With respect to Quest 2.5A, analyses of mission task submissions suggested that student descriptions of the processes depicted in the diagrams varied in terms of completeness. Some students provided nearly complete details about each process diagram, but the majority offered incomplete or implicit descriptions (See Table H2 in Appendix H for illustrative submissions of each type). Meanwhile, two students either denied that the diagrams carried any meaning or omitted any detail about the processes. This suggests that the scientists' diagrams provided all but two students with an opportunity to formulate basic descriptions of erosion and eutrophication, albeit to varying degrees of specificity. At the same time, a timescaled analysis of events also considered this Quest in terms of both the interactions that generated the mission task submission and the interactions that the mission task arranged. In this sense, the analysis considered activities in terms of both their unique emergence in this curricular enactment and the designs that both frustrated and facilitated it (Wenger, 1998).

In order to understand the relationship between the reciprocity between classroom interactions and the mission task, a content log coordinated data along both timescales in the sixth grade study. With respect to Quest 2.5A, the researcher was able to document a range of instances in which students interacted around or with the mission task. However, as the general description of the enactment alluded to, the classroom was often quiet. In reviewing multiple recordings of different groups during relatively more talkative moments, the utterances rarely amounted to discursive interactions. For this reason, interactional data is sporadic and often disjointed.

Given the description of classroom interaction in the preceding paragraph, the first excerpt of interactional data is somewhat poignant. After reviewing volumes of data that each provided different perspective on the happenings of one sixth grade science class, a chronological content log identified when the first student began Mission 2.5 (day 5) and, with it, Quest 2.5A. The log also tracked subsequent instances in which the Quest was either typed or talked about. This descriptive procedure generated a constellation of roughly 30 log entries associated with the "Sorting Out Diagrams" mission task. Most cases were brief utterances such as when one boy asked another to quickly summarize the farming diagram before the class period ended. The excerpt presented here, however, was a relatively longer five-message email thread between two boys who sat beside one another throughout the enactment. Because email logs did not include a timestamp, it is unclear how many were sent during class, but they were all sent on day five of the enactment. The thread shows the two students deliberating over

exactly who is causing the fish problem and some of the ways they might be doing so. Importantly, the boys continue to negotiate what the diagrams (referred to as "scrolls" in the emails) mean in light of their prior interviews and data analyses.

Excerpt 4.3.

Quester: Frank
Recipient(s): Gary
Subject: QA
Colin -
i found that everyone is contributing. Read the scrolls

Quester: Gary
Recipient(s): Frank
Subject: RE: QA
Yea, I Know. gee, the loggers sure think that floating logs is good for the river

Quester: Frank
Recipient(s): Gary
Subject: RE: QA
Also, a scroll said that some sediments from the boats are falling off. K-Fly [fishing outfit] is not nice to fishy!

Quester: Gary
Recipient(s): Frank
Subject: RE: QA
How do you know? Noone said that

Quester: Frank
Recipient(s): Gary
Subject: Possible Solution
I think I know why the fish are dying. It is because of "stuff" flowing into the water. If grass was planted, fertilizer and mud wouldn't run into the water.

This email thread shows the students sharing information about the diagrams and debating the meaning of the fishing diagram. Equally importantly, the final email reveals Frank's attempt to progressively recontextualize the Taiga scenario in terms of the diagrams and one solution they suggest. This interaction represents interactional events that aim to make sense of the Taiga scenario in terms of scientific processes. It illustrates a concrete opportunity to learn—one arranged by

liminal transitions. At the same time, any student interaction that centered on these diagrams represented an uncommon occurrence, particularly one of this length and via email. With respect to this study, the example illuminates possibilities for class-wide learning, but one that did not occur at the whole-class level here.

The other mission task associated with this secondary mission presented a farm expansion proposal. The task questions implied that students should use one of the previously discussed diagrams to explain that while the proposal presented a solution to one Taiga community's need, it also amplified an existing problem. In this sense, Quest 2.5B presented a complementary context to both the preceding diagrams and the curricular scenario. Paralleling students' explanations of the diagrams, all but one response related the farming proposal to both the farming diagram and the Taiga farming community with meaningful degrees of ecological detail. Interestingly, two students discussed the proposal in terms of the socio-political problems it created, introducing an unanticipated but equally relevant interpretation of the proposal. For these reasons, the second liminal mission task also appeared to provide students with meaningful opportunities to learn through complementary contexts.

At the same time, student interactions around this mission task remained equally non-communicative. Excerpt 4.4 provides a more representative instance of infrequent student interactions around the task. In this interaction, two girls seated beside one another converse about Quest 2.5B, which they refer to as the Mulu Proposal.

Excerpt 4.4

Sarah: I'm giving my advice about the Mulu Proposal
Janice: What're you going to say? ((pause))
Sarah: Huh?
Janice: What're you going to say? About the Mulu Proposal
Sarah: Oh! well ((pause)) they want more land
Janice: Do you think you should give it to them?
[S3A7_02-20-07.mp3 @7:38]

This brief interaction never arrived at an answer to Janice's question. What this transcript actually deletes from the interaction is the seemingly chaotic movements of twenty-six avatars in a shared virtual space, uniquely presented from twenty-six computer screen vantage points in the same room. Quite simply, the transcript omits the fact that Sarah and Janice are not sitting face-to-face in a quiet room, but instead are two among many who sometimes talk at one another as they navigate a multi-user virtual environment. What is representative about this interaction is that face-to-face interaction remains secondary to the activities taking place in the virtual environment. It may be more than just conjecture to ask if the email thread in excerpt 4.3 is the more relevant interaction precisely because it is computer-mediated. While this study does not deeply explore these communication pathways, the infrequency of extended interactions underscores a fundamental interpretive challenge for both understanding and designing to understand student participation.

A second set of missions tasks were presented as liminal transitions later in the curriculum, featured in Mission 3.5. It is noteworthy that only two-thirds of the sixth grade class and less than half of the fourth-grade class completed these tasks. On one hand, this relates to a consuming revision process associated with Quest 2. Six fourth grade students and four sixth grade students completed four (and up to seven) cycles of

revision each, while the classes, on average, engaged in over three and two cycles respectively. These revisions, in part, related to an innovative feedback strategy involving an NPC lab technician. However, the number of cycles just indicated suggests a disproportionate focus on Quest 2 revisions after initially receiving useful feedback. Moreover, an inspection of students' iterative edits to their Quest 2 submissions suggests increasingly unproductive revisions in student writing. On the other hand, the smaller completion rate is also generally consistent with implementations of similar versions of this curriculum in which small fractions of students failed to complete a subset of Missions (Barab et al., in press). Therefore, while the lower completion rates suggest that this latter secondary mission is not representative of the two classes in general, the real-world constraints of classroom learning and unanticipated constraints around Quest 2 feedback serve to qualify its inclusion in this analysis.

Mission Tasks: Textbox Dialogues

Bearing these limitations in mind, analyses of these latter liminal transitions centered on two textbox dialogue submissions. Students were to work in pairs to discuss two environmental reports from elsewhere in the mythical world of Atlantis and to submit individual responses. One of these reports presented a situation in which students were asked to determine potential problems in the proposed solution to chemical pollution. While all but one student selected incorrect responses, nearly half explained the problem well in their responses. Analyses of these outcomes parallel those associated with another report and will be discussed in terms of this "water filter" report. This report required students to evaluate which, if any, of the forms of information presented to them might help the people of Atlantis choose the best water filter. The question challenged

students to evaluate the amount and quality of evidence provided in each option and then to formulate a convincing argument about which option would best serve the people. Analyses of the submissions showed that response options varied widely in that students nearly evenly selected between three of the five options and provided varied reasons for their selections. It remained unclear if the meanings students made with the complementarity of this water filter problem supported learning. Therefore, analyses of students' written submissions suggest only that students indeed engaged the reports meaningfully and sometimes in terms of scientific evidence, but that the mission task did not illuminate if or how the liminal transition might support learning.

By design, both liminal transitions associated with Mission 3.5 arranged opportunities for pairs of students to debate each report. However, no peer discussions occurred among the subsets of students who engaged these reports. To be clear, individual students commented on the reports, but these utterances did not add up to interactions between students. These conversations ideally serve as a powerful learning opportunity in which students can "talk science" (Lemke, 1990) while, at the same time making it possible for learners' to share their protocols for meaning making with each other. The unanticipated absence of such discussion is considered further in the following chapter on design (chapter 4). Therefore, while the written submissions associated with this mission task and the observable interactions underlying them remain obscured, considering them in relation to the sequence of mission tasks that preceded and followed it provide a different perspective.

A final consideration of the textbox dialogues associated with the water filter report compares it with the submissions preceding (Quest 3) and following (Quest 4) this

report. Each Quest relates to an instance of time travel and specifically asks students to enlist evidence in their explanations of what went wrong with the Ranger's solution in the near future and what went right in the distant future, respectively. The analysis of these Quests together with the liminal transition considers trends across these tasks. In this instance, the analysis was a theory-driven consideration of the first of four learning standards, which considers evaluating claims based on the amount and quality of evidence provided. Of 15 students who completed all three writing submissions, analysis suggested that two students enlisted evidence in all three submissions and eight enlisted evidence in the water filter report and subsequently in their Quest 4 submissions. This trend, at the very least, is consistent with the assumption that liminal transitions can transform learner trajectories in practicing science, specifically the use of evidence.

Examining this event in terms of interactions, individual mission tasks, and overall missions reflects a timescaled approach to analysis (Lemke, 2000). While the inter-relations between each recurring cycle are obviously most compelling, an observable trend at one level signals a locus of refinement for subsequent design iterations. Nevertheless, these findings have only pointed with an elbow at the phenomenon they aim to understand, and they underscore the importance of not only supporting but also revealing student participation at multiple levels. The present design provided continuity across Missions 3, 3.5, and 4 that, in turn, enabled a sequenced analysis of submissions. It did not, however, generate meaningful patterns of activity in terms of writing submission or interactions. These design tensions are considered further in the next chapter.

Mission Tasks: Feedback

Liminal transitions aimed not only to engage learners with multiple contexts, but also to leverage this engagement in order to foster re-interpretations of the context and, in turn, to expand student participation and the subsequent unfolding of events. To this end, both sets of liminal transitions additionally provided students with feedback to support learning. The two Quests associated with "helping Jesse" in Mission 2.5 incorporated teachers' comments as is discussed in the next section. Meanwhile, the reports associated with Mission 3.5, which were generally shorter than Quests, provided more elaborate but general feedback written from the perspective of the Atlantian Council NPC, which is discussed immediately afterwards. Both teacher feedback and general NPC feedback provided opportunities for students to reconsider the fish problem and reorganize potential solutions; in this way, they aimed to support student learning.

Feedback from teacher via Quests. The teachers provided general comments at the end of each Quest in order to guide subsequent revision or to acknowledge approval. In general, only brief, generic comments were appended to the farming proposal (Quest 2.5B), such as "thank you, I will consider that. – Ranger Bartle" Both teachers focused more specific comments on the scientific diagrams (Quest 2.5A). Due to the complexity of the task and the diagrams, these comments most often centered on clarifying writing goals for resubmissions. In this sense, the majority of teacher feedback redirected students to the curriculum and the opportunities it afforded, but did not provide further opportunities in and of themselves, as was intended in the design.

Feedback via conversational rubrics. The latter strategy used in Mission 3.5 leverages a conversational feedback strategy developed across a series of innovative formative assessment studies (Hickey & Zuiker, 2003; Hickey et al., 2006). By providing non-specific but targeted feedback and a four-step conversation routine, Mission 3.5 feedback aimed to support small groups of students as they discussed answers to Atlantis reports. Like all of Mission 3.5, this feedback was embedded along the game-based curricular pathway with respect to learners' roles as field scientists. Specifically, an Atlantian Council Member, Lan, recast each problem in terms of the underlying consistencies it shared with Taiga.

While only very few 4th graders reached the mission, two-thirds of the sixth grade class completed it. None of the students engaged the reports or the feedback through conversations, or even in pairs. These changes relate to the design of the activity and are discussed in chapter 5. Moreover, because revisions to the reports were voluntary, most students likewise did not submit revisions. At the same time, in spite of the many who did not enlist the feedback to revise their response, the revisions of the four who did suggested that its embedment provided opportunities to reflect on and revise these new problems. In one case, the process further developed the revised submission and is discussed below. It is important to note at the outset that the teacher identified this student as one of the more academically accomplished students in all of four of his sixth grade classes. Given limited engagement with the feedback provided and the uncommon achievements of this student, the example serves as an illuminative case.

Excerpt 4.5 shows Carson's initial written submission to the pollution report. In it, he evaluates if returning heated water to a river solves a factory's existing water pollution problems or if it presents new problems for either the factory or the communities up- and downstream.

Excerpt 4.5

1. a) This is a good solution for the businesses, and for the people downstream.
2. This is a good choice for the stream and the people because of the harmlessness of the water. When water is used to cool the machines, it can still be returned to the stream. The water might be a little warm, but it will cool off very quickly in the cold stream. Plus, the towns upstream from Burma won't be affected, and the ones downstream would only face slightly warmer water. [Carson, S3-Bluegill Stream Report]

Carson provides a defensible response in which he qualifies thermal pollution as relatively minor because it quickly dissipates. However, he formulates a different response after reading Lan's general comments about solutions and the unanticipated problems that can result. (To be clear, Carson did not discuss the report, the feedback, or his answer with other students between submissions.) His revised response in excerpt 4.6 presents a more nuanced consideration of the indirect effects of heated water downstream of the factory.

Excerpt 4.6

1. e) None of the above.
2. Despite being sure about my first hypothesis, I am now rethinking it. The new temperature of the water will affect only the areas downstream. The change in temperature could kill some of the fish population, thereby reducing the income of local fishing companies. Also, the water might not have the affect on the machines that is expected. In that, the industrial area would be wasting its time. However, town A would not be affected.

[Carson, S3-Bluegill Stream Revision]

In this revision, Carson suggests that although thermal pollution dissipates quickly, it may still have an effect on the fish. In turn it may also have an effect on fishing companies, and therefore only some, but not all, downstream towns will be affected. The process of engaging in complementary contexts evidenced here reveals not only a successful mediational transition but an increasingly productive and nuanced instance of one as well.

Carson's submissions are consonant with his response in an interview one day later, after completing the curriculum. It is unclear how liminal transitions shaped subsequent participation with the final Mission, but Carson's overview of the lessons learned in Taiga on the last day of the implementation reflect a similar degree of appreciation for the complexities and interdependencies that such a liminal transition would afford. Excerpt 4.7 is his response when asked what he might tell Ranger Bartle if his Taiga experience began again in the year 2007.

Excerpt 4.7

Carson: I think I'd tell him you can't just tell someone to do something. That you have to tell someone to do multiple smaller things, it seems. Cause when he tried cutting off the Mulu fertilizer, they ended up having to try to sell land to the loggers or buy land from the loggers and it sets off a chain reaction if you don't look at every angle of it. So do small like one small thing for one group, another for another group, and another for a third group. just keep layering on for each group one part of the time so it all evens out. That's what I thought about it [Carson, S3V10_02-27-07 (Mission 4 complete)]

Carson describes the succession of solutions to the Taiga fish problem in terms of chain reactions and a progressive strategy for solving the problem by layering on additional

constraints, as necessary. He similarly described the thermal pollution in terms of a chain of reactions that only affects fish populations directly but the town indirectly.

In summary, this section discussed ways in which liminal transitions supported learning by considering written submissions associated with mission tasks. These mission tasks were also considered in terms of the moment-to-moment interactions that underlie them as well as the broader Taiga Missions of which they are one part. In particular, an email thread illustrated the dialectics of polycontextuality made possible while face-to-face interactions underscored that these instances were uncommon and therein illustrative of a broader interpretive challenge. These challenges have important implications that will be discussed in the final chapter of this dissertation.

Liminal Transitions for Revealing Knowing

In illuminating students' trajectories of participation, liminal transitions can also make science visible for inspection as a process of knowing. In this sense, science content is not simply the formal understandings of a discipline, but rather a process of formalizing understanding. In his sociological study of science, Latour (1987) contrasted these perspectives in terms of a "ready-made" science of well-defined notions like erosion or gravity and a "science-in-the-making" that these formalized notions often obscure. Ready-made notions represent systematically disambiguated and transformed versions of experiences with the world that are "viewed from one particular position, made sense of within a restricted domain of scientific inquiry, and brought into language by an expression embedded in a semantically nearly closed vocabulary" (Rommetveit, 1998, p. 229). In contrast to knowing science in terms of these seemingly finalized

disciplinary achievements, this section considers knowing as a concrete and studiable process of refining knowledgeable participation through transactions with the Taiga environment and between individuals.

Liminal transitions provided opportunities to "see" knowing in terms of transitions and, in particular, the writing submissions associated with them. The previous section overviewed these submissions for Missions 2.5 and 3.5. This section builds on these overviews and the sequenced analysis of individuals' multiple submissions that together defined the longer-timescale events—Taiga Missions. In considering these less frequently recurring cycles, liminal transitions provide perspective on the curriculum and the ways in which students productively enlist it in complementary situations.

Liminal transitions constitute an alternative view on transfer and one that generates a concrete and studiable means of doing so, as the following examples illustrate. Excerpts 4.1 and 4.2 presented two students' initial attempts to explain the Taiga fish problem in terms of water quality indicators. They aimed to "see" the virtual river in terms of a chemical profile (i.e., pH, temperature) and to write about the relations these profiles revealed. In those excerpts, neither Jason nor Randal wrote with an appreciation for the systemic interdependencies within the Taiga ecology. Later in this sequence of mission tasks however, they engaged the same Mission 3.5 report as Carson did in the previous section. This "Bluegill Stream" report (see complete written report in Appendix C) alluded to chemical pollution that could be eliminated if hot water was returned to the stream. The report again engaged students in "seeing" systemic interdependence in terms of these water quality profiles. Doing so was crucial to evaluating the report and proposing a solution to the Atlantian Council. In particular,

temperature as an indicator value provided a useful affordance with which to engage this particular situation and interpret an ecological imbalance that the proposed solution imposed. Such an appreciation is expressed in Jason's response to the Bluegill Stream report in excerpt 4.8.

Excerpt 4.8

```
1. e) None of the above.
2. I do not think that they should even try to fix the
   temperature of the water because when they put the hot
   water back in the [stream] it might stress the fish.
[Jason, P-Bluegill Stream Report, 01/29/07@8:55am]
```

Here, Jason contended that the heated water associated with the proposed solution in the report would not be good for the communities downriver of this factory. His response specifically qualifies hot water in terms of thermal pollution and its effects on the fish population, which suggests that, unlike his early Quest 2 submission, Jason has interpreted some degree of relational interdependence. In contrast, examining the ways that Randal responded to the same report reveals a different interpretation of the problem in excerpt 4.9.

Excerpt 4.9

```
1. a) This is a good solution for the businesses, and for
   the people downstream.
2. It's good because it doesn't use any chemicals.
[Randal, P-Bluegill Stream Report, 01/29/07@9:03am]
```

This solution benefited all communities along the river, as Randal argued, because it eliminated chemical pollution. However, the response fails to appreciate, or at least to include, the possible dangers of returning hot water to the stream. Exchanging thermal for chemical pollution may have represented an improvement. In fact, many students argued that hot water was a "lesser evil" of sorts over chemical pollution, but this remains, at best, indeterminate in Randal's response. Comparing these two students' sequences of

written submissions, excerpts 4.8 and 4.9 illustrate some of the differences that engaging with transitional contexts made visible with respect to one report and in relation to both students' preceding engagement during an earlier Mission.

Submissions associated with liminal transitions also provided the teacher with a perspective on students' ongoing participation with Taiga. As one example from the sixth grade class, Aisha's interpretation of the scientific diagrams associated with Quest 3 is presented in excerpt 4.10.

Excerpt 4.10

> The fishers are probably shown in the diagram because in each picture there are fish. 2.The scientists' were trying to show that what are causing less fish in Taiga. 3. I don't think the diagram is important because it doesn't explain very much.
> [Aisha, S3-SoDR1]

This is an incomplete Quest 3 response because it only discusses the diagrams associated with the sport fishing outfit and omits the remaining other two, reflecting her confusion around this Quest as discussed earlier in this chapter. More importantly, Aisha's response denies that the diagram affords new appreciation of the relationship between fishing and the fish problem.

To this end, Aisha's response prompts the teacher, Jack, to engage her in a face-to-face conversation. What is noteworthy in his effort to help Aisha imbue the diagram with meaning is the coupling of the diagram with the additional worksheet incorporated into study 2. As discussed above, the worksheet represented a modest refinement that aims to illuminate the relational interdependence of Taiga groups. Jack interprets this worksheet and the one diagram that Aisha discussed relative to one another in order to organize an initial interpretation of the overall Taiga ecology. Figure 4.2 presents an

image of Jack and Aisha discussing the Quest 3 fishing diagram and the field notebook worksheet

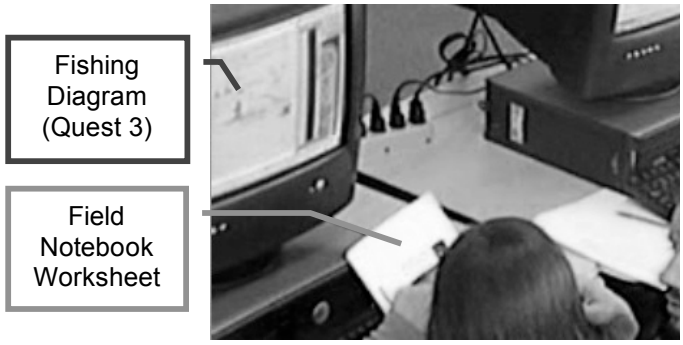


Figure 4.2 Classroom image of discussion with Taiga Quest 3 diagram and field notebook worksheet [S3V1B_02-23-07@32:38]

In effect, Jack embeds the processes illustrated in the diagrams along the pathway of the river and in connection to the water quality indicator data already generated in order to engage Aisha with the broader Taiga context. In so doing, Jack has arranged curricular resources to support a concrete and studiable process of refining and reinterpreting Taiga. That is, notions like erosion and eutrophication are not provided "ready made" (Latour, 1987) but rather represent an achievement arrived at through (re)interpretations of Taiga together with the diagrams. It is precisely these interpretations with the diagrams that represent transitions for progressively recontextualizing Taiga with respect to science. At the same time, this case also illustrates the ambiguity between learning and knowing in situative perspectives. Individuals are always already engaged in pervasive transactions with their material and informational environments. Therefore, all efforts to understand learning are inevitably opportunities to support learning.

In conclusion, this chapter has described liminal transitions as activities that support learning and reveal knowing about and beyond the curriculum. Findings from

class-wide analyses of students' mission tasks coupled with considerations of both the interactions underlying them and the Missions of which they are part converged to illuminate the enactment of designed activities. In terms of interactions, an illustrative instance showed peers progressively recontextualizing two situations in terms of their complementarity (excerpt 4.3), while a more representative instance highlighted a discussion that remained disjointed (excerpt 4.4). In terms of mission tasks, a series of writing submissions presented an uncommon instance of the use of feedback. In terms of Missions, sequences of writing submissions showed how liminal transitions make knowing visible. Altogether, these situations illuminate curricular phenomena (i.e., turbidity from logging) as instances of scientific concepts (i.e., erosion) and not as single instantiations of that concept. Moreover, they aimed to do so by preserving students' agency in appreciating these polycontextual affordances. In the next chapter, liminal transitions are considered again in terms of the design features underlying the construct.

CHAPTER 5

DESIGN CONSIDERATIONS

Overview

This dissertation set out, in part, to explore plausible design principles that might guide game-based pedagogies for supporting and understanding general consequences of learning. In order to understand the value of embedding liminal transitions along game-based curricular pathways, this chapter considers the mediating influences of liminal transition designs for both supporting learning and evolving theoretical understanding of the general consequences of learning.

Designing for Complementarity

Two strategies design for liminal transitions along game-based trajectories of participation with *The Taiga Fishkill Project* curriculum. In this dissertation, both strategies leveraged students' experiences with the Quest Atlantis multi-user virtual environment and Taiga. This section considers the role each strategy played in relation to liminal transitions and their potential contribution to principled designs for supporting and understanding the general consequences of learning as an alternative to transfer. Several cases from across the two studies were selected on the basis of their informational value with respect to students' trajectories of participation. The aim of this section is to illuminate the ways students engaged these designs as intended as well as the ways engagement led to unanticipated mutations.

Polycontextuality: Working with multiple contexts

The curriculum in both studies enmeshed a range of science content and learning standards within the context of Taiga National Park. The notion of polycontextuality additionally underscores the possibility of intermeshing science content that is situated in Taiga with complementary contexts that differ by some degree. Students considered a proposal and ambiguous, hand-written diagrams about Taiga in Mission 2.5 and different problems around Atlantis in Mission 3.5. These situations represent mediational transitions because they featured simulated or indexed relations with Taiga and specifically polycontextual mediation because they presented different representations of the targeted content and standards or suggested different situations to which they also relate. In this way, each liminal transition provides opportunities to extend situated understandings by simultaneously thinking about and beyond Taiga. The various examples presented below illustrate ways in which students engaged these complementary contexts as designed and how they inform refinements for subsequent designs of liminal transitions.

Interpretations of polycontextuality during interviews

In engaging these new situations, students appreciated connections with Taiga in a range of ways. Three sixth grade students' responses during brief interviews conducted at their computers during or soon after completing liminal transitions illustrate this variation explicitly. Of 26 interviews, students described similar features or formulated a common theme across curricular and liminal situations in all but six and these excerpts are representative of these instances. In excerpt 5.1, Jenny comments on the Bluegill Stream report, which concerns one proposed solution to a factory's chemical pollution at the

midpoint between streamside communities. She is explaining why the Council member, Lan, would ask her to work on this report.

Excerpt 5.1

Jenny: They're about communities that have similar problem to Taiga. They're both about like the stream is unhealthy and they have to figure out what is causing or what would be the solution to help the problem

[Jenny, S3V4_02-23-7]

Jenny enlists both situations to draw two surface-level connections, namely that both situations involve (1) unhealthy streams and rivers that (2) require solutions. More relevant to solving both problems, however, is an underlying appreciation of water quality indicators such as temperature and the systemic relations between a process like thermal pollution and objects like fresh water organisms. Thus, her response suggests a relatively basic interconnection.

In contrast, Gary enlists both situations in response to a similar question, but seems to enlist interpretations of both contexts in order to respond to the question. He was asked to speculate about why the NPC Lan asked him to work on the water filter, which asks students to evaluate different forms of evidence in order to decide if either of two filters is relatively better than the other. In response to this question, Gary briefly explains, "well it might be using scientific data to prove a problem" [Gary, S3V6_02-27-07]. This comment suggests that he has reified the water filter report and Taiga in terms of a scientific principle about evidence that underlies both. Appreciating these overlapping features affords the progressive recontextualization of both scenarios in terms of meanings defined not within but across situations.

Comparing Jenny and Gary's interview responses suggests a range of interpretations that enlist more and less relevant consistencies between situations. These,

in turn, afford more and less productive transitions across situations. These interview responses along with twelve others provided useful insights about the notion of polycontextuality because most responses explicitly detailed different affordances or described similar affordances differently.

A third example drawn from interviews presents one student's much broader appreciation of the Taiga situation. While the examples above suggest surface- and deep-level appreciations, this third presents successive interpretations uncommon to student interviews. In excerpt 5.2, Kate explains what she is doing in class on day 12 of the enactment. The explanation is relatively brief because she was, in effect, summarizing on camera an impromptu discussion between the author and her that had occurred moments earlier. In this summary, she explains the fishing diagram in relation to Taiga and draws a broader connection across the two worlds she has investigated two years apart.

Excerpt 5.2

Kate: I think that when the when Jesse showed the papers it showed that the fishers were churning the water so that might be affecting the fish because the sediment in the soil rises up. And I realized from the pictures that I took that the water was darker in 2009 than 2007. `[Kate, S3V3_02-26-07.mp4]`

Kate's response enlists the diagram to recast Taiga in succession. First, she describes how the diagrams frame the fishing outfits activities in relation to water quality (i.e., churned water raises sediment and affects the fish). Across time, she enlists this description to explain a trend that she notes in time-series photographs of the Taiga river. In this sense, Kate has organized an interpretation in terms of a summary of human activities and of these activities across time, reflecting multiple levels of understanding the polycontextual affordances of liminal transitions.

Each of these interview comments provides important insights into understanding design but also presents an analytical tension as well. The interview setting and the veiled research questions framing them constitute activities that differ from the trajectories of participation emerging along the curriculum's mission pathway. This is not to say that interview responses are meaningless to this study, rather that there meaningfulness emerges through a context in which language is mediated differently. In this sense, interview settings impose different constraints on language-in-use. Interviewer questions engaged students in framing an interpretation of polycontextual affordances while obscuring a process of fostering polycontextual affordances. Therefore, while the interviews are suggestive, more important insights lie in student engagement directly with the design.

Instances of polycontextuality during enactments

An equally important aspect of designing for polycontextualization was arranging for peer collaborations and discussions. The dialectics of discursive interaction around liminal transitions generate a concrete and studiable process of progressive recontextualization within and between situations (e.g., Taiga and the Bluegill Stream Report). In order to interpret the problem and construct responses featured in liminal transitions, student groups ideally enlist language to establish and maintain a common focus and to negotiate the meaning of experiences in terms of their respective trajectories of participation. While written formulations and spoken utterances alike contribute to what Roth (2004, 2005) describes as a learner's natural protocols for making sense of and imposing structure on experiences, each does so differently. In order to analyze liminal transitions, these differences are conceptualized along different cycles of recursion, or

timescales (Lemke, 2000). Students periodically submitted written responses to Quests and other shorter prompts as part of their missions. Each of these submissions built on periodically recurring interactions with Taiga and its non-player characters (NPCs) and, in many cases, interactions with neighboring peers or the whole class, such as Becky's debriefings with fourth graders at the end of each class period. These recurring interactions, namely the collaborative discussions among pairs of students, relate to episodes of liminal transitions and ideally illuminate students' natural protocols for progressively recontextualizing their experiences, all of which contribute to but are obscured in artifacts.

Content logs and transcribed interactions from both enactments suggest that liminal transitions infrequently arranged rich topics for peer conversation. However, the fourth grade end-of-class debriefings provided illustrative examples of the possibilities and signal that supporting peer conversations are an important locus of refinement. A paradigmatic example of such an intermeshing discussion occurred during a whole-class debriefing late in the fourth grade enactment and relates to an initial series of interactions between students and the NPC Lan in the Taiga cave. Lan asks each individual student to consider how two maps hanging on a cave wall might relate to one another. These maps depict Taiga and an urban riverscape called Cinder Creek. Excerpt 5.3 begins with Becky's question about student motivation. One student responds by expressing his interest in QA's Cinder Creek world as presented in the above interaction with Lan. This response initiates a brief whole-class discussion about Cinder Creek.

Excerpt 5.3

1	Teacher:	How many of you are still motivated and excited to keep moving
2		forward? We've got more work to do. ((Seven students each raise a
3		hand.))
4	Mike:	I wanna do Cinder Creek
5	Teacher:	You wanna do Cinder Creek? What do you **know** about
6		Cinder Creek?
7	Mac V.:	Well there's a railroad track and a big factory
8	Teacher:	What do you think is the problem in Cinder Creek? Do you
9		think there is a problem there?
10	Mike:	Same as the problem as Taiga just worse
11	Teacher:	Worse (.) Is it different
12	Leslie:	Well it's different in a way cause there's like factories=
13	students:	=Yeah there's factories ((multiple students at once))
14	Mike:	I think its worse cause there's cars and roads and trains
15	Michelle:	Yeah so there'll be different things affecting it but it's
16		basically the same Quest just in a different place

[PV1_01-30-07B@2:23]

In response to the teacher's three guiding questions (lines 5-6, 8-9, and 11), students provided details about Cinder Creek's urban landscape. With prompting, comments progressively relate Cinder Creek to Taiga and a conclusion that, while different, the same field investigation ("Quest" in line 16) applies.

Taiga, in excerpt 5.3, is a prior context that serves as a resource for foregrounding some aspects of the Cinder Creek map (e.g., railroad tracks and factories then later roads, cars, and trains) in order to construct it as "basically the same" ecological investigation with different factors. In turn, it recasts Taiga as only one instance of what Michelle ambiguously characterizes as a "Quest." In this way, the reciprocity between Cinder Creek and Taiga fosters concrete and studiable process for constructing a polycontextual appreciation. This whole-class discussion represents one of several conversations through which Becky enlisted liminal transition scenarios productively to support students in

simultaneously thinking about and beyond Taiga. Nevertheless, the discussion centered on the teacher's, and not students', utterances in this example.

Mission 3.5, in particular, was designed to provide pairs of students with opportunities to discuss and negotiate liminal transitions but, as the enactments revealed, they may have compromised what collaboration they fostered. These collaborations were arranged in two ways. First, they presented the mission as a "team" activity because only pairs could successfully navigate entry. Each pair of students needed to synchronize their avatars' actions in order to simultaneously "knock" on different doors before either would open. This design effectively engaged all students in collaborative activity, including the sixth graders who previously worked alone. In this sense, it presented a powerful design for rearranging classroom interaction through gaming technologies. Excerpt 5.4 presents chat entries that illustrate this collaborative process between two girls who typically worked alone.

Excerpt 5.4

```
11:28:54 AM        Jenny   Does anyone have to enter the cave?
11:30:10 AM        Casey   some one open the door with me!
11:30:15 AM        Jenny   kate, do u have to go in the
                           cave?
11:30:41 AM        Casey   jenny open the door with me
11:30:48 AM        Jenny   okay
11:30:49 AM        Casey   ill go around the other side
11:30:54 AM        Jenny   okay
11:31:08 AM        Jenny   yeah
11:31:20 AM        Casey   yeah we did it!
[SC_02-22-07, Taiga2]
```

The first five entries above show Casey and Jenny. searching for partners before eventually pairing up and coordinating their entry into the Taiga cave. Once inside, however, the strategy for supporting collaboration shifted from the constraints of an

interactive rule set (i.e., unlocking the cave door) to the interactive dialogue with the NPC Lan.

Upon entering the cave, Lan's dialogue with students congratulated each team and directed them to continue their collaboration as they analyzed the reports. Yet, rather than building on the coordinated activity to sustain collaboration, this second strategy was more often overlooked or ignored by students. In fact, analyses of group interactions suggest that the design may have actually encouraged students to work alone in spite of these directions as the conversation in excerpt 5.4 illustrates. Nate and Dan were discussing the Taiga-Cinder Creek map comparison prompt, the same one discussed during the 4th grade debriefing in excerpt 5.3. The transcript begins after sixth grader Nate has already asked his classmate, Dan, to explain the cave maps task to him.

Excerpt 5.5

1	Dan:	This is … these are two things
2	Nate:	Do they go together?
3	Dan:	That's basically the same as that.
4	Nate:	So they're just like under each other↑ or is this like
5	Dan:	This one's a totally different world (.) Its called Cinder Creek
6	Nate:	Yeah (.) but does this run into this (.) or how are they exactly
7		the same
8	Dan:	No they're like (.) they have the same problems (.) you just fill
9		that out and you should (1.0) you have to do that

[S3A3_02-20-07@00:13-01:40]

This question and answer sequence provided opportunities to discuss potential interconnections between the two maps. Nate formulated two possibilities in asking if one river is either "under" (line 4) or "run[s] into" (line 6) the other; Dan likewise presented two possibilities in stating that the maps are "basically the same" (line 3) and later explicating this sameness in terms of "problems" (line 8). Much like the fourth grade discussion in excerpt 5.3, the pair make comparisons that work to construct

underlying consistencies. However, Dan thereafter shifts the topic to an overview of the requirements for Nate to complete. This interaction is significant because it contrasts the goals communicated in Lan's dialogue with the goals communicated in the activity structures. While the two boys discussed the inter-relatedness of the two maps, the interaction orients to requirements that Dan takes up to close the conversation. In this case, the requirement is a text box that invites individual students to type independent responses, which Dan points out, and then to proceed with Mission 3.5, which Nate does soon after.

Given these competing influences, the interaction illuminates a critical relationship between the game-based interactivity that arranges QA mission progress, in general, and the structures and directions that support collaborative goals with the liminal transitions in Mission 3.5 specifically. On the one hand, the simple but successful collaborations realized in order to navigate the interactive rules for entering the cave demonstrate a powerful affordance of game-based technologies. On the other hand, the relatively complex collaborations necessary to establish and maintain a common focus on interpreting and negotiating polycontextual affordances demonstrates a critical design tension for liminal transitions.

These Mission 3.5 liminal transition designs aim to leverage language-in-use in order to make concrete and studiable a process of progressive recontextualization. Such a process provides a means of appreciating polycontextual affordances and understanding the general consequences of learning. The design strategy in this study presented written steps via an NPC that aimed to establish a collaborative framework but required students to interpret, enact, and maintain this structure as an extension of their game-based

trajectories of participation. In part, this reflects interest in evolving theory about the ways that game-based roles support productive transitions discussed in the next section. At the same time, the analyses in this section suggest that the tasks that follow each discussion, in effect, often actually accompanied them. That is, the activity goal of negotiating polycontextual meaning was mediated by the game-based ends through which it was realized. This reciprocity suggests a contradiction in the current design. The social interaction underlying discussion translated into required individual written responses available at the same time. Students resolved directions to collaborate and requests for individual answers by dissolving collaborations. Further underscoring this point is the immediacy with which other students came to this conclusion. Excerpt 5.6 presents chat entries while Casey is working on the first report and after she successfully coordinated entry into the cave.

Excerpt 5.6

11:39:20AM	Casey	connie do you want to do the report with me...ive already done it and they told me to go to the computer in the corner with someone
[…]		
11:40:51AM	Casey	nevermind connie you dont need a partner i think

[SC_02-23-07, Taiga2]

Casey quickly concluded that the tasks could be, and possibly should be, done alone and told Connie so. As with Dan and Nate, this interaction also suggests that the present design undermined the conversations that these reports aimed to generate.

In conclusion, this section argued that designing for polycontextuality engaged students in productive discussions but that the design itself presents a contradiction in individual-oriented classroom dynamics such as this particular 6th grade. Designing for

polycontextuality in this game space arranged opportunities for students to progressively recontextualize the Taiga scenario in terms of other situations. Student interviews and multiple whole-class discussions in the 4th grade classroom demonstrated that the alternative situations entailed in liminal transitions did, in fact, provide activities through which students talked about and beyond the immediate situation in terms of complementary properties of liminal transitions. At the same time, the reciprocity between activity goals and their reflection in the game space illuminate a tension and a contradiction that inform the iterative refinement of game-based liminal transitions. The next section examines these same activities from a different vantage point, considering the ways that prolepsis invites learners to expand their roles in the game space through liminal transitions.

Prolepsis: Embedding and linking context

While appreciating that polycontextual affordances support productive transitions into new activities and situations, this dissertation assumed that it is equally necessary to frame the context not only in terms of practices but also the roles through which students engage with liminal transitions (Packer & Goicoechea, 2000; Wenger, 1998). The design of these transitions provided degrees of continuity with a player's existing roles in the primary QA Missions. A proleptic strategy, in contrast, re-arranges contextual particulars in order to induce presuppositions about a player's role.

Both Mission 2.5 and 3.5 positioned players differently relative to the primary Taiga missions. Each of these missions introduced new NPCs along the curricular pathway whose presence entails the player's increasing competence as a field investigator. In the first, another Quester issues a plea for assistance (Mission 2.5) and in

the second an Atlantian expert requests support (Mission 3.5). A presumption across these situations is that the player understands what actually remains unstated, namely recognition of the player's experiences with Taiga and the competence it suggests. By entailing degrees of competence, these situations arrange for anticipatory comprehension, cueing the learner to expect to understand the problems that follow. To be clear, these proleptic arrangements remain contingent; the player may or may not engage liminal transitions in these ways. However, in leveraging the player's ongoing transactions with the Taiga environment and Taiga NPCs, these situations shift from the possibility of understanding prolepsis to an increasing probability or likelihood of recognizing it. Therefore, this section considers efforts to enlist intended roles along curricular pathways in order to support and expand learner roles as field investigators.

At base, prolepsis using a context, which does not necessarily involve language, depends upon the ways players make meaning with these non-verbal cues. For example, one contextual cue for arranging prolepsis was to use a youthful avatar for the NPC Jesse in Mission 2.5, one that resembles those available to players and not the more mature-looking NPCs. This and other cues served to induce presuppositions about the activities that students complete with NPC Jesse and its implications for students' relative status in Taiga. However, arranging prolepsis in game-based pedagogy is contingent upon an interpretive exchange that a design (e.g., cues like an avatar's youthful appearance) can only approximate on the basis of the curricular pathway preceding it.

Student reactions suggested that these complex exchanges often proved meaningful in potentially proleptic ways. For example, upon seeing NPC Jesse, a 4th grade student observed, "Hey, he looks like we do." The comment interprets NPC

Jesse's appearance relative to the player's own avatar, suggesting a degree of symmetry, if not affiliation, between avatars. Also, the personal pronoun "we" further suggests a similar degree of affiliation with his own player avatar such that he has projected his experience onto his avatar and vice versa, which is a common stance or positioning in game play (Gee, 2005b). The student's interpretation becomes key when juxtaposed against NPC Jesse's subsequent request for help. That a similar looking avatar would look to the student for help ideally induces presuppositions about their relative status and triggers a search for an explanation why. In a similar example, a sixth grade student asked the researcher where to find NPC Jesse while literally standing beside the NPC Jesse avatar. The student explained that he assumed NPC Jesse was simply another Quester and had not attempted to engage him, which again underscores interpretations of NPC Jesse's appearance. Both also suggest ways in which interactions with NPC Jesse were recognized from the outset as uncommon, if not altogether unexpected, because his 3D avatar, unlike other NPCs, was also youthful.

In addition to "seeing" Jesse differently from other NPCs, several students also engaged both NPCs associated with liminal transitions differently. Until Mission 2.5, NPC Jesse was relatively peripheral, offering intermittent comments about his mounting struggle to complete two Quests that foreshadowed his later plea for help. Meanwhile, in Mission 3.5 the Atlantian council member, Lan, was an altogether novel NPC sequestered in a cave and accessible to players only during the mission. The spoken comment in excerpt 5.7 illustrates one sixth grader's apparent surprise upon encountering Lan in the Taiga cave. His comment is non-specifically directed to the group of four nearby boys with whom he collaborated throughout the curriculum.

Excerpt 5.7

Will: Who's this guy? Who's this guy? Is this Lan? Hey, I'm talking to Lan right now. Hey, I'm talking to Lan.
[S3A2_02-26-07@40:25]

Will's questions suggest that he is curious and the repeated "hey" signal his intention to be heard. None among the group responds, however, and so Will proceeded with mission activities.

A second example presents a more critical orientation. Two sixth grade students working at neighboring computers discussed the curriculum periodically, including Taiga NPCs among their topics, however, their discussion about NPC Jesse was noteworthy for its irreverence. Brad is preparing to begin Mission 2.5 in excerpt 5.8 when the two talk aloud about why Jesse is a "punk."

Excerpt 5.8

1 Brad: okay now I've gotta go help Jesse
2 Carson: Jesse's a punk
3 Brad: yeah
4 Carson: he's like (inaudible speech) how's it going↑
5 Brad: how's it going homey↑
6 Carson: ((looking at Brad's computer screen)) yeah that's him and I'm
7 like
8 Brad: Its like guess what (inaudible) you're not a real gangster (.)
9 you **think** you're a real gangster
[S3A4_02-23-07@24:38]

NPC Jesse is denigrated as a "punk" (line 2) and a disingenuous "real gangster" (lines 8-9). Meanwhile, Carson's inaudible speech and subsequent salutation in line 4 seem to be a mocking paraphrase of NPC Jesse's dialogue, given the slurring and fluctuating intonation with which it is delivered. The pair's critical orientation in this interaction is peculiar for two reasons. First, Brad, Carson, and others nearby had discussed NPCs before and after this discussion of NPC Jesse and all of these other instances were

typically informational in nature or otherwise benign. The second reason this is peculiar is because Mission 2.5 represents the first shift in the relative status of students' roles as field investigators. Given this background, one possible interpretation of this exchange relates to prolepsis and the potentially transformative effect of inducing presuppositions about Brad's and Carson's status, if not their competence. In other words, the apparent change of status may have invited these boys to assume a different relationship with NPC Jesse, one in which he was a punk.

The above excerpts illustrate ways that students engaged with proleptic designs features in Missions 2.5 and 3.5. The aim in this proleptic strategy was to reposition the learners' role in terms of the increasing competence their mission progress underscored, while also maintaining continuity with a broader trajectory of participation. The range of interactions above suggests that students meaningfully engaged in interpretive exchanges with the game design in order to induce presuppositions.

While student interactions with Taiga or with one another proved illustrative but indeterminate, interviews provided a different perspective. Responses from multiple students made meaning of the proleptic cues (e.g., NPC appearance and status) against the backdrop of the liminal transition activities that followed, and these meanings suggested a sense of increasing competence. For example, two sixth graders, Gary and Jenny, were among several students who responded to questions about their Mission 3.5 experience. In excerpt 5.9, Gary explains why Lan recruited him.

Excerpt 5.9

1	Steve:	So why do you think he asked you during Mission 3 and
2		not during Mission 1 (.) or Mission 2
3	Gary:	Because on Mission 1 and Mission 2 you were still
4		collecting data (.) You weren't tackling big problems like

this [Mission 3.5 council report].
Steve: So then specifically why do you think Lan is asking you during Mission 3?
Gary: Well, he'd think (.) I (.) you'd think during Mission 3 (.) he'd think that you'd already have a good view on everything. He'd think that you **know** about Taiga well enough to compare and contrast it to other different details.
[S3V6_02-27-07]

Gary here contrasted the work of interviewing Taiga characters and analyzing water samples in Missions 1 and 2 with "big problems" (line 4) presented in the Mission 3.5 reports. While it remains unclear how these brief episodes were relatively larger in his view, one possible explanation is the compressed span of time represented in each brief scenario. Gary also speculated that Lan recruited him because his work in Taiga afforded him "a good view on everything" (lines 9-10). These responses suggest that Gary viewed Mission 3.5 in terms of his preceding trajectory of participation with the curriculum and, moreover, that these opportunities legitimate his work with Lan.

In response to a similar question, Jenny responds in terms of her work on the Mission 2.5 with Jesse, as is shown in excerpt 5.10.

Excerpt 5.10
Steve: Why do you think Lan asked you
Jenny: Because before when I was working with Jesse we showed really good teamwork so he thought I was a good candidate to help him make decisions
[S3V4_02-23-07]

Jenny suggested that Lan recruited her because she collaborated successfully with the NPC Jesse during Mission 2.5. Like Gary in excerpt 5.9, she viewed her work with Lan in terms of her preceding experiences, but focused exclusively on the earlier liminal transitions. Both students' interpretations are reasonable and suggest that they viewed the Mission in terms of their prior successes in Taiga. In excerpt 5.9, the Mission 3.5 reports

also suggested to Gary an evolving role in which he was progressively capable of bigger and bigger problems.

Altogether, the fourth and sixth grade enactments suggested that many students initially engaged their work with liminal transitions differently than the primary Taiga missions. This reflects design strategies to juxtapose liminal transitions against the recurring patterns in the primary missions (e.g., using a youthful avatar as an NPC). Interviews also provided insight into these experiences, suggesting that several students interpreted the situation arranged for the mission in terms of their preceding work and successes therein. In considering if and how prolepsis serves to support and understand productive transitions, these examples suggest a tractable approach to leveraging learning in terms of the roles that students develop across a trajectory of participation. Prolepsis as a design strategy took advantage of player's evolving roles to implicitly signal the learner's increasing competence across missions. Further, in making this assumption, students might engage subsequent secondary mission problems (i.e., Jesse's Quests and Lan's reports) in light of their previous work and its relevant particulars. To be clear, this section did not set out to prove the efficacy of prolepsis but to understand the plausibility of its function in game-based pedagogy.

In conclusion, this chapter has discussed the design strategies for supporting liminal transitions. Through interviews, peer interactions, and whole class discussions, the enactment of these designs were illuminated, but interpretive challenges precluded deeper appreciation of the design affordances of prolepsis. The final chapter of findings takes a decidedly different perspective of liminal transitions, stepping back some

distances to appreciate it within the broader context of the complete curriculum that Taiga Missions constructed.

CHAPTER 6

QUANTITATIVE RESULTS

Overview

The final question raised in this study aimed to understand the general consequences of liminal transitions from the perspective of the broader educational system in which curricula and schooling operate. To this end, the design was considered in terms of its impact on individual performance measures and in comparison to the transitions afforded by conventional formative assessment activities in which students individually complete and review a constellation of curriculum-oriented items.

Multi-Level Assessment

Pre- and post-implementation data for each of three assessments featured the targeted science content and standards. Each is defined in terms of a continuum of referent generality (Snow, 1974). Given this study of learning and its general consequences, this continuum was further specified in terms of instructional sensitivity (Ruiz-Primo et al., 2002) and operationalized in terms of a multi-level assessment framework (Hickey & Zuiker, 2003; Hickey et al., 2006). The framework for this study includes two different levels of instructional sensitivity (i.e., proximal and distal) and two different facets of measurement (i.e., performance assessment and multiple-choice tests).

Administration and Scoring

A member of the research team administered all assessments within one week of the beginning and end of each implementation. Fourth grade students completed the pre

and post multiple-choice tests and the performance assessment across two separate forty-five minute periods on consecutive days. Sixth grade students complete all assessment in single 90-minute periods before and after the implementation. Two raters scored all open-ended responses for the curriculum-oriented, proximal performance assessments in both the 4th and 6th grade studies after achieving requisite inter-rater reliability (Pearson's r = 0.91).

Lastly, Table 6.1 summarizes the number of students who completed each of the missions or quizzes featured in the curriculum across all three enactments in study 1 and study 2. This data profiles the extent to which each class completed each mission in the curriculum.

TABLE 6.1

Number of Completed Missions by Class

	No. of students who completed each mission		
Formative Mission	4th Liminal (n=17)	6th Liminal (n=26)	6th (n=24)
1	17	26	24
2	13	26	24
2.5	10	25	21[1]
3	7	25	22
3.5	7	19	17[1]
4	5	17	17

[1] completed informal quizzes instead of liminal transitions

This profile of implementation fidelity establishes that both sixth grade classes had similar opportunities to learn through the curriculum because roughly equal numbers of students completed each mission. Also, the diminishing percentages of completed missions reflect game-based learning ecologies in which students' moment-to-moment engagement with tasks literally determines progress through the curriculum. While each

student would ideally complete all missions, the sixth grade distributions above likely reflect realistic rates of individual student progress. Some students finished the curriculum early and others did not finish.

4th Grade Learning Outcomes

Paired sample t-tests revealed differences that were statistically unlikely to have occurred by chance on the curriculum-oriented, proximal-level performance assessment [$t(13)=7.1$, $p<0.000$] and multiple-choice assessment [$t(13)=3.9$, $p<0.002$] as well as the standards-oriented, distal-level multiple-choice test [$t(13)=3.3$, $p<0.006$]. Graphs of pre-post means for each assessment appear in Figure 6.1 and descriptive statistics are provided in Appendix J. Proximal level items featured the same formal science concepts and standards targeted in the curriculum, but the wordings and graphic representations that invoked these resources varied by degrees from the ways they were embedded in *The Taiga Fishkill Project* curriculum. Meanwhile, class-wide learning gains on the standards-oriented, distal-level multiple-choice assessment suggest that students also performed significantly better on items that featured a range of science concepts and representations related closely to the target standards but more or less randomly to the curriculum. Altogether, these results suggest that 4th grade enactment supported learning across a range of contexts with direct and indirect relations to the curricular content and context. In particular, impacting distal measures through a single curricular unit represented an ambitious goal and the statistically significant improvement represents an ambitious goal and noteworthy outcome.

The effects sizes of these differences are an equally noteworthy outcome. Measures of Cohen's *d* show roughly two, one, and one-half increases across assessments

(see Figure 6.2), reflecting a spread of effects consistent with previous research enlisting multi-level assessment strategies (Hickey et al,, 2006). Moreover, this underscores that the curriculum was not only statistically significant, but pedagogically significant as well. Lastly, these data obviously do not distinguish the relative influence of one aspect of the curriculum over another. Liminal transitions necessarily complement curricular experiences and these results support no specific claims about their relative influence.

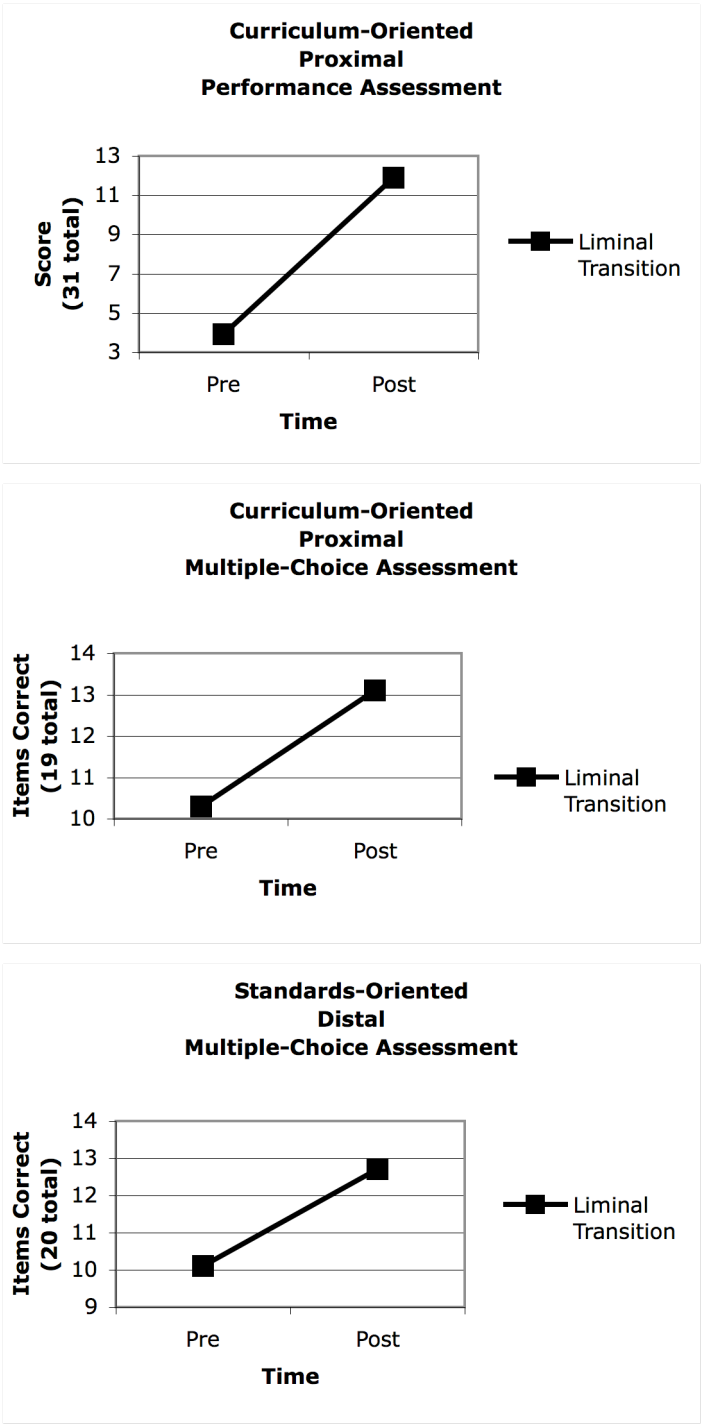


Figure 6.1 Graphs of pre-post means for fourth-grade multi-level assessments

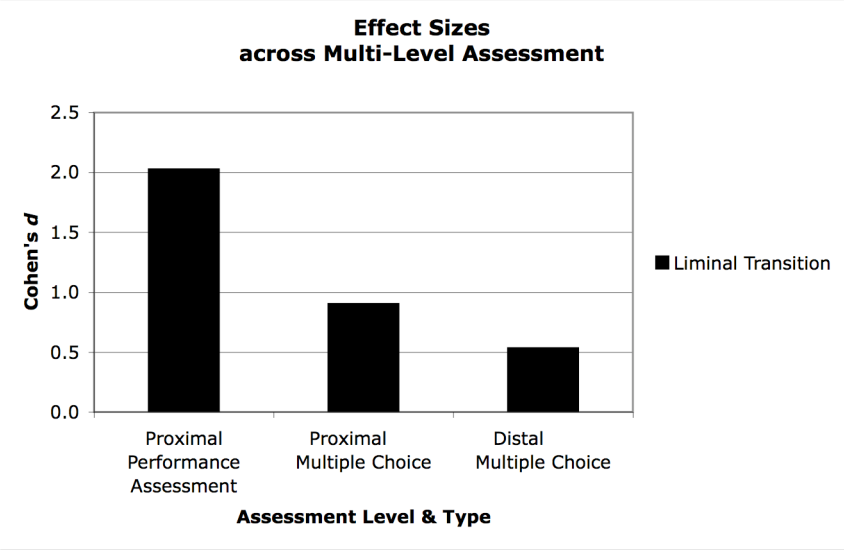


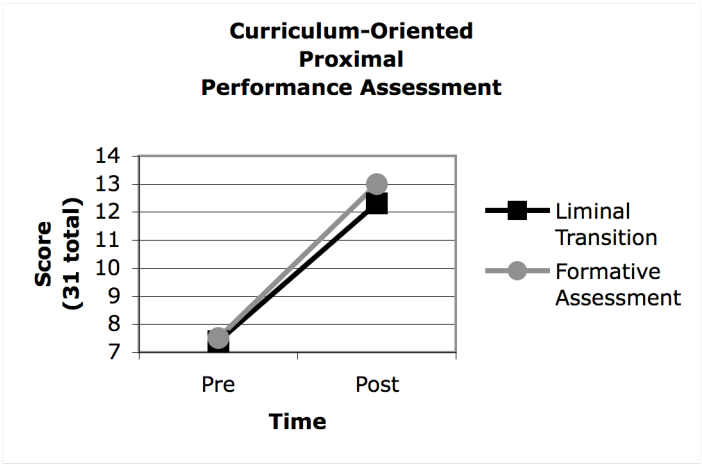
Figure 6.2 Comparison of multi-level assessment effect sizes for sixth grade study conditions

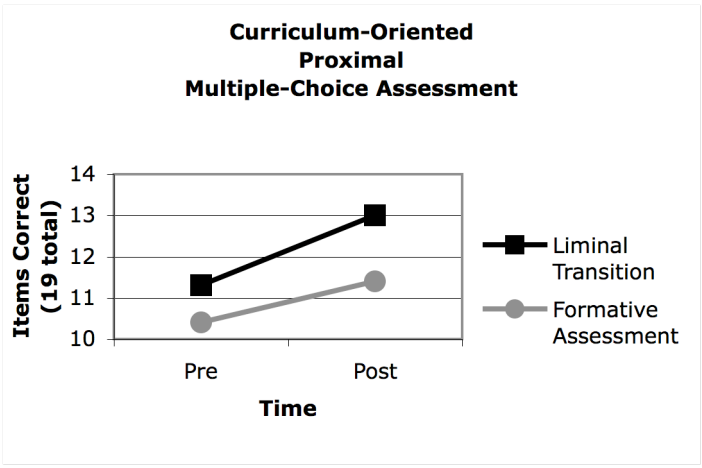
6th Grade Learning Outcomes

Paired sample t-tests again revealed significant differences on both the curriculum-oriented, proximal-level performance assessment [$t(23)=7.3$, $p<0.000$] and multiple-choice test [$t(20)=3.0$, $p<0.007$] and additionally revealed significant gains on the standards-oriented, distal-level multiple-choice assessment [$t(20)=3.7$, $p<0.001$]. A graph of these pre-post means appears in Figure 6.3 and descriptive statistics are provided in Appendix J. These results suggest that the 6th grade enactment supported learning across a range of contexts with both direct and indirect relations. Like the fourth grade outcomes, these results are particularly dramatic at the distal level where single curricular units typically fail to make a significant impact. At the same time, these results do not distinguish possible synergies between liminal transitions and the primary curriculum. In order to generate different perspective on the value of game-based transitions on learning, different assessment conditions were compared.

Quasi-Experimental Comparison of Sixth Grade Conditions

Group by time repeated measures analysis of variance revealed no significant differences between conditions. The curriculum-oriented, proximal performance assessment [$F(1, 45)=0.17$, $p<0.68$], curriculum-oriented, proximal multiple-choice test [$F(1, 42)=1.9$, $p<0.18$], or the standards-oriented, distal multiple-choice test [$F(1, 42)=0.80$, $p<0.4$]. At the same time, while the variance explained in a design may sometimes be trivial, the results may still be important.





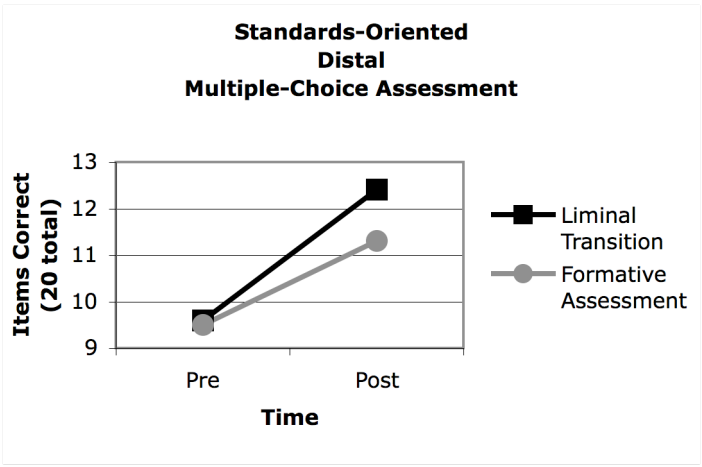


Figure 6.3 Graphs of pre-post means for sixth grade multi-level assessments

Multi-level assessments consider a spread of effects and these effects lie along a theorized continuum of referent generality (Snow, 1974) that profiles general

consequences of learning. Each increasingly distant multi-level assessment frames items around either increasingly different representations of targeted content and standards or increasingly general or abstract representations. In this way, they arrange an assessment idealized pathway for understanding the general consequences of learning (Hickey et al., 2006). Given the variance within the conditions, differences between conditions did not reach the level traditionally deemed statistically unlikely. Thompson (2006) argues that effect sizes may still be an important statistic to report. The interpretation of an effect size is not rigidly defined by pre-determined benchmarks (e.g., Cohen, 1969). When the context of this study suggests that small effects can reasonably be assumed to generate cumulatively large effects, then effect sizes provide an important perspective that statistical significance testing can obscure (Abelson, 1985). In the context of this study, it is reasonable to assume that liminal transitions or formative assessment transitions could be incorporated into multiple curricula across a school year, yielding a cumulative effect over time. Against this backdrop, the sizes of the observed effects for each condition appear in Figure 6.4.

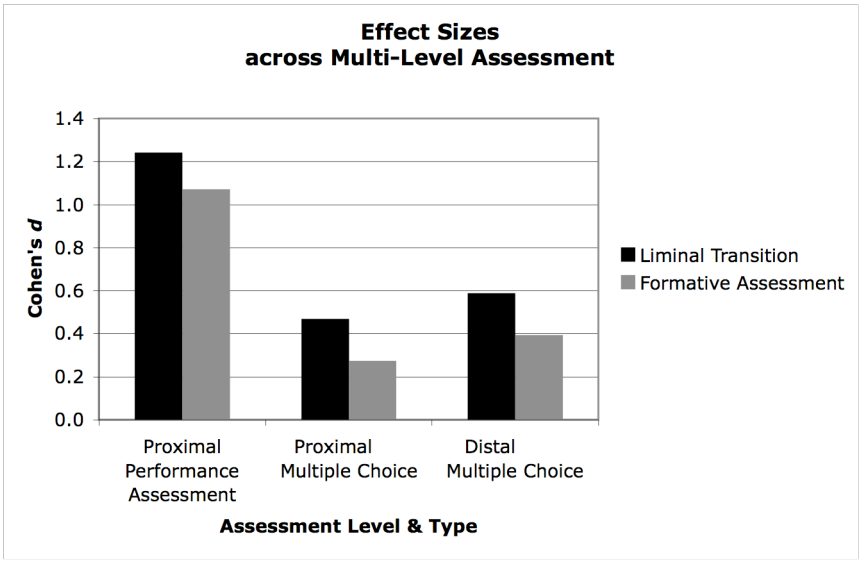


Figure 6.4 Comparison of multi-level assessment effect sizes for sixth grade study conditions

The magnitude of the curriculum-oriented, proximal-level performance assessment suggests conventionally "large" effects for both groups (Cohen, 1969). At the same time, the relative differences in effect sizes between conditions suggest that liminal transitions were larger by just under 0.2 for each level and type of assessment. This observation is not to suggest that the effect sizes reported in study two or the differences in effect sizes between conditions are in some way significant. Instead, it suggests that significance may not serve the context of this study (Abelson, 1985; Thompson, 2006).

Students in each condition performed demonstrably better on open-ended questions about water quality problems related to a detailed scenario that was similar to the one presented in *The Taiga Fishkill Project* curriculum. Moreover, these observed effect sizes suggest that students who participated in the liminal transition condition, in general, performed better than students who participated in the formative assessment condition. The differences in relative magnitude of each condition, though not statistically unlikely to have occurred by chance, consistently suggest that the liminal

transition condition had a greater effect as referent generality increases and instructional sensitivity decreases. In this light, the trend across levels and types of assessment suggests that, in spite of being statistical unlikely, the liminal transition condition may have leveraged students' curricular experiences not only differently, but also more productively than did formative assessment condition.

In conclusion, this chapter has reported the results of multi-level assessment measures in terms of statistical significance and effect sizes. These results suggest that student understanding of the four target learning standards statistically increased across the respective implementations. Effect sizes generally illustrate the decreasing instructional sensitivity across levels. Moreover, they provide a benchmark for understanding the relative impact of liminal and formative assessment transitions. To this end, the observed trend in effect sizes suggests that liminal transitions provide a promising avenue of future inquiry as a recurring feature across curricula. In the next chapter, the findings from across chapters 4 through 6 will be discussed along with their implications, particularly with regard to future research.

CHAPTER 7

CONCLUSIONS & IMPLICATIONS

Conclusions

This dissertation explored the general consequences of situated learning in terms of the content-context relations that students navigate in a game-based curriculum. Two studies aimed to engineer a form of situated learning that reveals general consequences of curricular experiences while also developing means of supporting ongoing learning. These transitional activities can be understood as assessments for learning that address both doing science and being scientific. Clearly, other contexts and scenarios must be considered with a wider array of opportunities not only within a curriculum but across curricula and throughout courses as well. However, examining how liminal transitions transform learning ecologies represents an important first step towards generating design principles and refining design features to better illuminate theoretical interests. It also expands the set of investigations with which to develop theory and progressively refine the questions asked in subsequent studies.

In general, pursuing this research involved inherent limitations because findings were, in large measure, grounded in the specific qualitative interpretations of the researcher. Commitment to a particular focus always prioritizes some data over others and risks enlisting only selective or anecdotal evidence. For these reasons, the researcher engages in the unavoidable and unending tensions of maintaining rigorous sense of method while formulating a particular account of classroom life (Roth, 2005; Silverman,

2001). To this end, the results presented in chapter 4 aimed to qualify excerpts as either representative of the enactment or critical examples of the design.

This chapter considers the qualitative and quantitative results reported in chapter 4. It focuses on the ways in which liminal transitions transformed scientific practices in relation to the primary curriculum. In this way, liminal transitions represent activities that support learning and reveal knowing in terms of ongoing participation. It also focuses on what these transformations suggest about the design of liminal transitions and game-based pedagogies more broadly.

Learning and Knowing with Liminal Transitions

Liminal transitions embedded at two points along the curricular pathway provided opportunities to transform scientific practices and evolve scientific roles emerging in *The Taiga Fishkill Project* curriculum. Moreover, these complementary opportunities served to intermesh scientific concepts such that students appreciated notions like erosion as not only about the curriculum but also extending beyond it as well. In these transitions, student participation was mediated by preceding activities with the curriculum, on the one hand, and by various present moment scenarios, on the other. This section summarizes analyses of individual trajectories through liminal transitions and the unfolding curriculum beyond.

Situating Generalizations with Multiple Contexts

Analyses revealed a variety of interactions through which the primary curriculum was recast in terms of the situations presented in liminal episodes. An email thread and face-to-face conversation (excerpt 4.3 and 4.4) illustrated the possibilities for meaningful student interactions and the more common limitations encountered in this dissertation. A

whole-class discussion (excerpt 5.3) similarly leveraged liminal transitions to recast their work as relevant to other situations beyond Taiga. On the one hand, the first set of liminal transitions involving other scientists' diagrams and one stakeholder's proposed solution engaged many students with competing interpretations of Taiga. Excerpts illustrated one student's outright rejection of the diagrams (excerpt 4.10) and two students' debate about them (excerpt 4.3). On the other hand, the second set of liminal transitions involving other scenarios beyond Taiga engaged students in the work of interpreting new situations in terms of the curricular scenario but proved difficult to understand in the absence of focused peer conversations. In one uncommon but illuminative instance, one student's efforts to refine his interpretation (excerpts 4.5 and 4.6) appeared to, if only partially, further recontextualize Taiga in terms of liminal transitions (excerpt 4.7). This suggests that the strategic embedment of complementary contexts can support learners in appreciating deeply contextualized inquiry in terms of scientific concepts with broader consequence. These results together illustrate ways in which liminal transitions support general consequences of learning by intermeshing multiple contexts. Appreciating interconnections in this way is consistent with the notion of polycontextuality (Y. Engeström, 1987; Y. Engeström, Engeström, & Karkkainen, 1995) as well as the related notions of "situated generalization" (Carraher & Schliemann, 2002, p. 5), "intercontextuality" (Floriani, 1993, p. 255), "situated abstraction" (Noss, Hoyles, & Pozzi, 2002), and "abstraction in context" (Hershkowitz, Schwarz, & Dreyfus, 2001). These terms convey a complementary sense of the interpenetration of situated learning and the indivisibility of meaning and context, no matter how refined or abstracted meanings might be. They also reflect concerns about forms of learning that begin with

formalized artifacts or abstractions. If abstraction is a process of science (Latour, 1987), then the informational products, apart from the process through which they are refined, represent incomplete understandings. In terms of the present discussion, the inseparability of content and context is a dialectic that several excerpts illustrate in terms of liminal transitions (excerpts 4.3 and 4.11). These complementary contexts engaged learners in a tentative process of generalizing through negotiations. In this sense they reflect an ontological commitment to relational views of learning and the inseparability of knower and known and an alternative perspective to transfer.

Expanding Roles through Transitions

It was argued that liminal transitions represent an ontological innovation distinct from notions like intercontextuality (Floriani, 1993) or situated generalization (Carraher & Schliemann, 2002, p. 5) because they support learning in terms of practices and roles. Designing with respect to learner roles represented an ambitious effort to engineer social positions in support of productive transitions. Specifically, the scenarios featured in liminal transitions projected an expanding role in order to scaffold participation across contexts. The ways that students commented about non-player characters (NPCs) and their use of the first-person pronouns to describe the actions of their avatars reflect common stances that game players take (Gee, 2005b). Interviews during liminal transitions suggested that students made productive interpretations about their changing roles (excerpt 5.9 and 5.10) in that they connected their work in the second liminal transition with earlier successes. Insofar as learning science involves both doing science (i.e., practices, tools) and being scientific (i.e., roles, values), these interviews illustrate

an often-omitted aspect of the general consequences of participating in authentic scientific activities.

At the same time, the larger corpus of classroom interaction remained ambiguous about how these roles represented or supported liminal transitions. Students may have interpreted the relative status implied by the liminal transitions in unanticipated ways (excerpt 5.8). In large measure, supporting and understanding learner roles and "being scientific" remained an interpretive challenge.

Designing for Transitions Liminally

In addition to understanding liminal transitions from the perspective of student trajectories of participation, this dissertation also considered them from a design perspective. This section discusses different ways that these scenarios were taken up in the enactments. Understanding what differences made a difference is important in order to formulate tentative design principles useful to other researchers and to inform refinements to subsequent studies through which liminal transitions can be evolved. Before considering these features, an important caveat is to recognize the limitations and constraints inherent to all design. That is, learning cannot be designed, but only designed for. It is only ever "frustrated or facilitated" (Wenger, 1998, p. 229) through design, underscoring a tension between what is intended by design and what actually emerges.

Liminality is an ontological innovation enlisted to conceptualize and support the general consequences of learning. The idea of liminal transitions drew on Beach's (1999) notion of mediational transitions to engage students in activities that extend beyond a curriculum and into activities along a continuum from classroom simulations to some form of partial or peripheral participation in real world communities. Employing game-

based methodologies and technologies, liminality was *designed for* in terms of practices and roles. Both of these aspects of participation are theoretically important in relational views of learning (e.g., Lave & Wenger, 1991; Wenger, 1998) and arguably rely one on the other (Packer & Goicoechea, 2000). With these complementary aspects of participation in mind, this dissertation designed for liminal transitions in terms of polycontextuality and prolepsis.

With respect to polycontextuality, different but complementary contexts presented in the curriculum proved useful in supporting learning during whole-class discussions (excerpt 5.3) and through peer collaboration (excerpt 4.3, 5.1, and 5.2). Interviews also suggested that students engaged the curriculum to make sense differently of liminal transition scenarios, from relatively surface to deep levels (excerpts 5.1 and 5.2 respectively). Written submissions likewise suggested that nearly all students had engaged with liminal transitions meaningfully though less meaningful submissions also occurred (excerpt 4.10). Moreover, instances of peer discussions over email (excerpt 4.3) and whole-class debriefings (excerpt 5.3) underscored the value of engaging multiple contexts dialectically through interaction. However, many opportunities to engage with the dialectics necessary to negotiate polycontextuality were either confined to interactions with computers or redirected to the computer after brief collaborations (excerpt 4.4 and 5.5). The conditions of collaboration communicated a double bind (Bateson, 1972) in which what was written and what was communicated were not the same and ultimately dissolved the collaborations into the individualized tasks that the activities required.

The various complementary contexts featured in liminal transitions were accompanied by design efforts to evolve students' gaming roles by means of prolepsis.

Interviews suggested that students linked their activities in liminal transitions with their evolving roles as field investigators and, in particular, their increasing competence (excerpt 5.9 and 5.10). At the same time, the wider array of students' gaming interactions and peer discussions were less conclusive. While the meanings made of the contextual cues that designed for prolepsis were consistent with the design intentions, it remained unclear if and how these meanings related to learner roles. These design tensions and interpretive challenges generate important implications and define a locus of refinement for future design studies that will be discussed later in this chapter.

Conclusions about Relative Value and Increasing Breadth

The multi-level assessment framework enlisted to understand this innovation provided classroom-wide profiles and a useful benchmark for understanding subsequent iterations of the design. Individual student trajectories of participation with both the curriculum and liminal transitions are reflected in assessments. To this end, the observed trend in effect sizes suggests that liminal transitions provide a promising avenue of future inquiry. The observed gains scores, given the variance, however, suggested that these differences were not statistically unlikely. Previous design studies that employed a multi-level assessment framework encountered similar challenges in obtaining statistical significance on proximal and distal outcomes in initial studies (Hickey et al., 2006). *The Taiga Fishkill Project* curriculum on which this dissertation now builds is a case in point (Barab et al., 2006; Barab et al., in press).

This framework is also useful for considering an evolving sense of validity theory. Validity arguments frame assessments in terms of particular epistemological positions and therefore concern "whether and how epistemological processes lead to

valid ontological outcomes (that is, with how mere experience gets you to true reality)" (Bruner, 2002, p. 8). However, the validity of the kinds of mediational transitions arranged by content tests may generate only a partial perspective on learning. Such a perspective addresses participation as a repertoire of disciplinary practices, but not disciplinary roles. These epistemic considerations alone do not reflect situative views of learning (e.g., Barab & Plucker, 2002; Lave & Wenger, 1991; Wenger, 1998) and may omit the crucial ontological outcomes associated with the roles that learners develop through participation (Packer & Goicoechea, 2000). These concerns about validity arguments are reflected in an emerging dialogue about the idea of testing (Moss et al., 2005; Moss et al., 2006). A multi-level assessment strategy enlists multiple rationalities that are "in play" in schooling (Hickey & Zuiker, 2003) and provide one means of juxtaposing the general consequences of learning. Understanding ways in which situated learning impacts a range of more discrete situations apart from a trajectory of participation represents an important consideration.

Limitations of the Dissertation

The author reported his reflexive efforts to document the progressive subjectivity of this study. Efforts to do so are essential to the social construction of knowledge because this reporting of the enactments of *The Taiga Fishkill Project* constitutes only one way of "seeing" with the data. While the analytical procedures section detailed the process of constructing this perspective, it necessarily remains perspectival. Because any way of seeing is reflexively also a way of not seeing the data, this report must be qualified. The author's efforts to redesign the curriculum fundamentally shaped the data generated in this dissertation. In exploring the construct of liminal transitions, this design

aimed to engineer some forms of participation for players and to exclude others. By the same token, the curriculum itself was enacted in classroom settings that further shaped engagement, rendering actors as not only players but also students. These fundamental influences, among others, provided some opportunities and limited others in this enactment. With regard to the specific studies presented, the dissertation generated a relatively small degree of observable, moment-to-moment interactions. While students were constantly engaged with the curriculum, engineering opportunities for discussion proved challenging. In this way, understanding the ways in which liminal transitions operated remained an interpretive challenge.

Implications

This final section considers implications based on these studies and discusses subsequent designs that follow from the insights emerging through this project. This dissertation aimed to leverage the opportunities that game-based pedagogies provide to, in effect, "play the game" of science (Gee, 2003b). Grounded in Whitehead's (1929) concerns about inert knowledge, situated learning runs the risk of a similarly inert fate if learners do not also have opportunities to "game their play." That is, if a student has not had opportunities to engage their experience with a curricular scenario as one instance of a broader system of activity, then the polycontextual affordances of that experience remain lifeless. Bereiter (1997, p. 286) suggests that "the main weakness of situated cognition is, it seems, precisely its situatedness." Arranging liminal transitions with respect to situated understandings provided opportunities to combat this apparent weakness. Each transition constituted an episode through which to think not only with

curricular experiences but to enlist them to think beyond the curriculum as well. In this way, situativity might belie its name and begin to build generalizations of consequence.

At the same time, situativity is not a misnomer. The work of generalization is intimately situated as well. Latour (1987) described the work of science to abstract meaning as a very concrete phenomenon. "To be sure, each stage of [refining ideas towards abstraction] simplified, punctualized and summarized the stage immediately below. But this activity of re-representation was very concrete indeed; it required pieces of paper, laboratories, instruments, tallies, tables, equations" (p. 241). The process of refining observations and patterns into abstract principles is situated in a process of representation and re-representation. That this process is concrete means that it is studiable as well. Liminal transitions aimed to make generalization and the general consequences of learning similarly concrete. By meshing complementary contexts to create mediational transitions (Beach, 1999), liminal transition afforded a process of polycontextual intermeshment. And by pairing students to enter a virtual cave and asking them to deliberate problems, the ensuing conversations might generate a concrete and studiable process of "intermeshing." To this end, gaming technologies in this dissertation demonstrated a near effortless capacity to actively engage students in the work of collaboration in order to enter a virtual cave. These technologies also seemed to demonstrate a powerful limitation in the form of a double bind that effectively dissolved collaborations into the individual submissions at which they arrived. An important conclusion from these polarizing effects of gaming technologies is not simply to engender collaborative goals in the work of polycontextual intermeshment, but to engender interactive goals in the work of collaboration. Negotiating meaning with and

across contexts may only require collaboration insofar as interactive rules that govern the curricular pathway arrange it.

A second important implication of liminal transitions is that they can inspire learners to pursue science beyond the curriculum. Rather than closing-off science as finished and complete, liminal transitions present science as open-ended and continuous and suggest pathways beyond the curriculum. The whole-class discussion from the fourth grade class (excerpt 4.11) reflects this sentiment. After the thirteenth class period, the teacher asked "How many of you are still motivated and excited to keep moving forward?" Mike's immediate response addressed one of the liminal transition scenarios: "I wanna do Cinder Creek." Insofar as "learning is a way of being in a social world, not a way of coming to know about it" (Hanks, 1991, p. 24), this comment reveals a more pervasive general consequence of learning with Taiga than incisive commentaries like, for example, the fact that partial solutions set "off a chain reaction if you don't look at every angle" (excerpt 4.6). Mike's comment expresses an uncommon degree of intentionality. It also reflects one way in which liminal transitions can anticipate interpretive challenges about the general consequences of learning in game-based pedagogy. That is, the general consequences of learning are not only to develop a keen sense of scientific practice but a willing disposition to practice science or, said differently, a commitment to doing "being scientific". It is this complementarity that underlies notions of learning as both practices and identities. These points underscore Lave's (1990, p. 325) argument presented at the outset of this dissertation. "Learners who understand what they are learning in terms that increasingly approach the breadth and depth of understanding of a master practitioner are likely to understand themselves to be

active agents in the appropriation of knowledge, and hence may act as active agents on their own behalf."

With regard to method, this study enlisted a timescales approach to organizing curricular events. The interpretive challenges alluded to in the limitations section above were, in part, addressed by considering liminal transitions not only in terms of interactional data but also in terms of the broader Missions within which they were situated. Considering events across these three layers provided not only insight into the enactment but also signaled that designing liminal transition across multiple levels of participation and therein along multiple timescales may generate a more elaborate data set for illuminating both the work of doing science and being scientific.

Related to these methodological implications, classroom interactions with game-based pedagogy often disappear behind a kind of digital curtain that presents new opportunities and challenges for instruction. Organizing classrooms and classroom discussions around virtual worlds that invite students to leave those classrooms creates a tension in the work of teachers. Balancing the opportunities that schooling and gaming provide represents an important intersection. One conclusion to be drawn from these studies is that the whole-class debriefings organized in the fourth grade provided an important opportunity for field investigators in Taiga to report back to their school before returning to class. That is to say, debriefings provided an opportunity to focus on the gaming experience in terms of its instructional goals. Leading but open-ended questions provided students with opportunities to share their experiences and strategies while offering the teacher perspective where her students had been.

Future Research

The analyses in this dissertation highlight liminal transitions as one possible strategy for understanding and supporting the general consequences of situated learning. However, further cycles of conjecture and implementation are needed in order to illuminate polycontextual intermeshment more robustly. Anticipating ongoing interpretive challenges inherent to micro-level analyses, it will be equally necessary to extend the analytical boundaries of liminal transitions beyond single curricula to the patterns of participation distributed across curricula and beyond formal schooling.

Translating situative theory into educational practice represents a reflexive effort because the enactment of these practices must, in turn, be accounted for in terms of theory. This is particularly the case in design studies. Coupling mediational transitions with an ontological innovation like liminality generated a visionary framework through which to explore not only what curricula afford but also to consider how much further they possibly might extend in the future. This study represents an effort to enrich understanding of situated learning and to envision the general consequences of situated learning, in terms of both the practices and the roles that evolve through participation.

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APPENDICES

Appendix A

Introductory Letter to Curriculum

Taiga National Park

ATLANTIS NATIONAL PARKS SERVICE

Date: March 9, 2006
From: Ranger Mals Bartle
To: All Questers
Subject: Taiga National Park

Overview

The Taiga Park Management has hired you to investigate an alarming environmental problem in the park. A few years ago we started to notice a decline in the number of almost all species of fish in the Taiga River. While fishing is a past time many people enjoy—and take quite seriously—the decline in fish is a sign of something very wrong with our waterway. I am sure you are aware that the water, the bugs, the fish, the birds, and even us, are all connected. That's why you have been hired: your job is to determine what is causing the fish decline, how we can work to stop it, and how to balance the needs of everyone who uses the forest.

Background to the Problem

Our park is known world wide as having the best sport fishing of any river environment. The users of the park are getting upset and blaming each other for the decline in fish. The park is expensive to manage and can barely afford to stay open. Now, some of the groups that pay for park facilities are threatening to take their operations elsewhere if we don't fix the problem.

Of course it would be nice if we had unlimited funds to manage the park just as a recreation and conservation area. However, the reality is that we need to make money to keep the park open. We manage the park so that it brings in enough money to maintain the forest ecosystem while still being the kind of place people will want to visit and use. There are three main groups that could individually or together impact the park and might be causing the decline in fish. These are the indigenous people, loggers, and fly fishers. (See Figure 1.)

Figure 1: map of Taiga National Park

First, the land to the north of the park is owned by indigenous Mulu land holders. The Taiga River passes through their land on its way to the park. The indigenous people have rights to the animals and fish on their land. I know that they support their people with the food they grow as well as the produce they sell to the local markets. They are good neighbors for us because they usually stay on their own land. In the past, their hunting, fishing, and trapping activities along the river have not been a problem for us. However, we don't know if they have made any changes in recent years that could be affecting the water or the land.

Second, about 40 years ago, long before I worked here, a lease was offered to Build-Rite Lumber to log trees in the park. This company has been very good for the park for a long time. They pay a large annual fee for the lease, they chop down trees only in the licensed areas of the park, and they replant trees after logging. Also, they maintain all of the roads in the park, and they are careful that their trucks do not damage the environment on the way to their mill in the south of the park. We gain a lot of money from the loggers working in the park, and it helps us to maintain most of services we offer.

Third, about 4 years ago, we allowed the K-Fly Fishing Company to run fishing tours in the park. At first they just brought only a few people each weekend to go fly fishing and camping in the center of the park. Then, two years ago, we held the Taiga Angling Competition, and hundreds of fishers came to the park and competed for a trophy. That was a great success and brought a lot of people, all paying park entrance fees. We have held two other competitions since that time, but with there being so few fish this year, we may have to cancel. The fly fishing company is considering moving to a new park because of the decline in fish. Losing their business would cost our park a lot of money and damage our reputation as the best sport fishing of any river environment.

Action Plan

We need to find a way to balance the needs of everyone who uses the park so that it can stay open and be preserved for future generations. Your investigation will begin soon. You will meet people in different areas of the park and ask them questions. The information they offer will help you begin to understand the causes of the problem. You will also write a report explaining the views of the different groups. Then, you will gather more information by asking more questions and by collecting water samples at three sites along the river. Using what you learned, you will write a report proposing a plan to solve the problem. Your plan must balance the needs of each of the groups that use the river and forest. The recommendations that you make might be adopted by the park management and hopefully will save our park.

Ranger Mals Bartle, Park Manager
Taiga National Park

Appendix B

Overview and Goals for Mission 2.5 Liminal Transitions

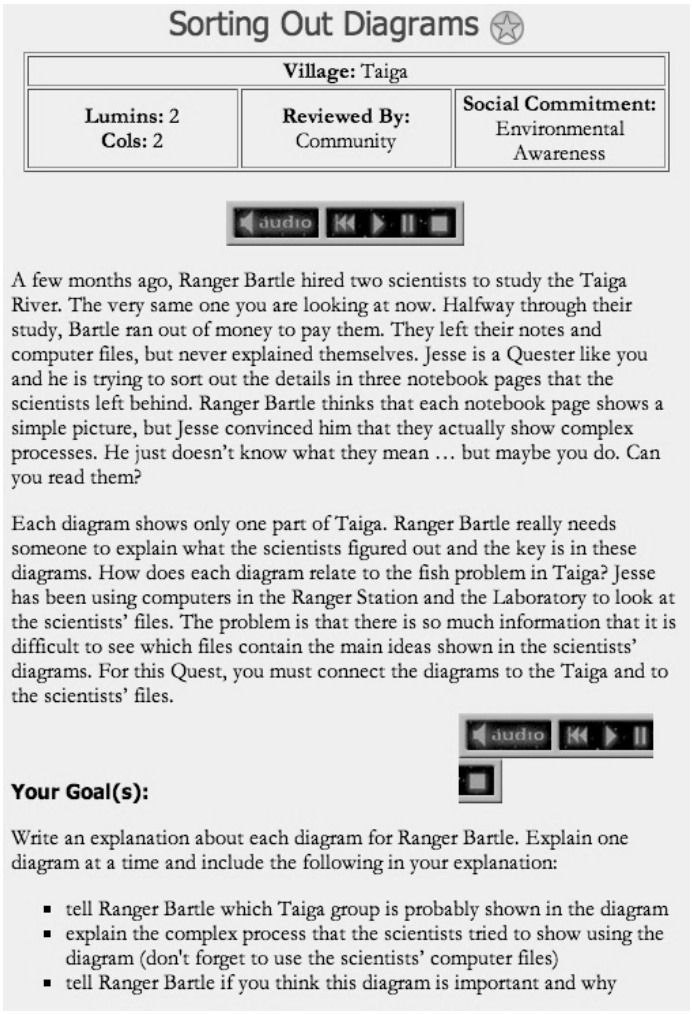
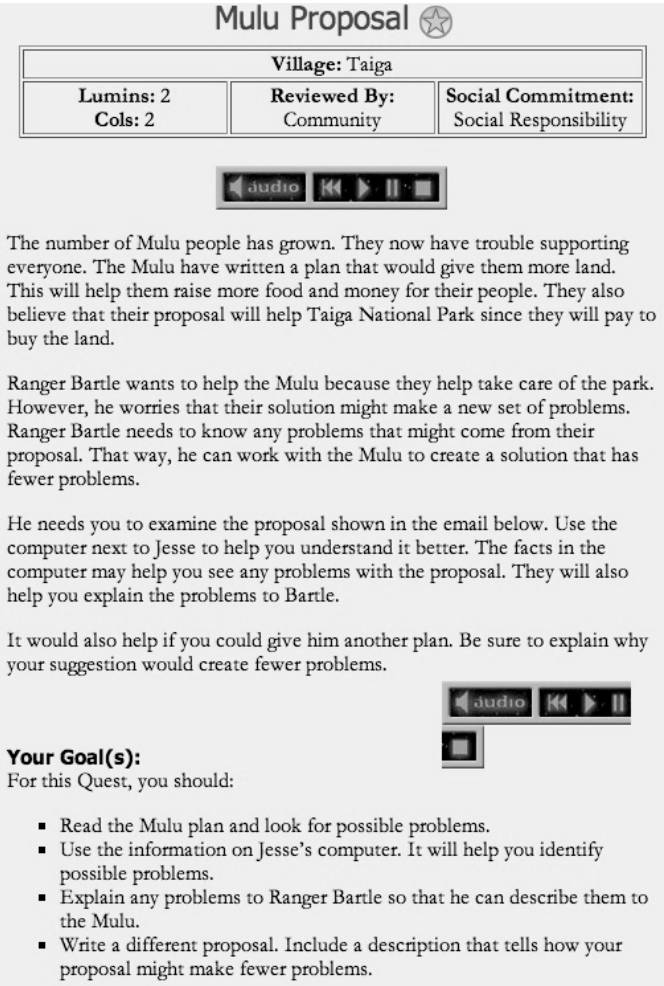


Figure B1 Quest 2.5A overview and goals



Mulu Proposal

Village: Taiga		
Lumins: 2 **Cols:** 2	**Reviewed By:** Community	**Social Commitment:** Social Responsibility

audio

The number of Mulu people has grown. They now have trouble supporting everyone. The Mulu have written a plan that would give them more land. This will help them raise more food and money for their people. They also believe that their proposal will help Taiga National Park since they will pay to buy the land.

Ranger Bartle wants to help the Mulu because they help take care of the park. However, he worries that their solution might make a new set of problems. Ranger Bartle needs to know any problems that might come from their proposal. That way, he can work with the Mulu to create a solution that has fewer problems.

He needs you to examine the proposal shown in the email below. Use the computer next to Jesse to help you understand it better. The facts in the computer may help you see any problems with the proposal. They will also help you explain the problems to Bartle.

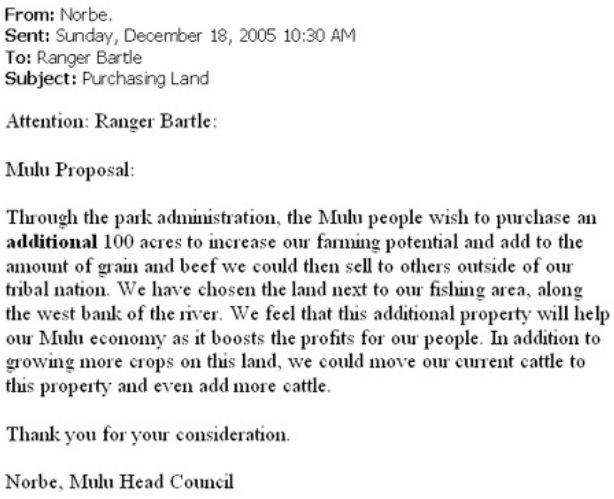
It would also help if you could give him another plan. Be sure to explain why your suggestion would create fewer problems.

audio

Your Goal(s):
For this Quest, you should:

- Read the Mulu plan and look for possible problems.
- Use the information on Jesse's computer. It will help you identify possible problems.
- Explain any problems to Ranger Bartle so that he can describe them to the Mulu.
- Write a different proposal. Include a description that tells how your proposal might make fewer problems.

Figure B2 Quest 2.5B overview and goals



From: Norbe.
Sent: Sunday, December 18, 2005 10:30 AM
To: Ranger Bartle
Subject: Purchasing Land

Attention: Ranger Bartle:

Mulu Proposal:

Through the park administration, the Mulu people wish to purchase an **additional** 100 acres to increase our farming potential and add to the amount of grain and beef we could then sell to others outside of our tribal nation. We have chosen the land next to our fishing area, along the west bank of the river. We feel that this additional property will help our Mulu economy as it boosts the profits for our people. In addition to growing more crops on this land, we could move our current cattle to this property and even add more cattle.

Thank you for your consideration.

Norbe, Mulu Head Council

Figure B3 Quest 2.5B Mulu proposal "email"

Appendix C

Text of Mission 3.5 Reports

Water Filter Report.

“Drinking water in Atlantis is becoming polluted. We must start filtering water in many lakes. *Clear Water*™ and *Hydroclean*™ both claim that their water filters are the best at cleaning water. You must decide what kind of evidence will help the Council. Some strategies have been suggested below. Is any of this evidence helpful?”

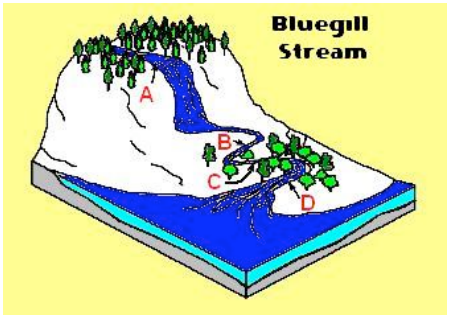
a) A community near a polluted lake said that fewer people get sick now that they use *Clear Water*™ filters.
b) A commercial claimed that *Hydroclean*™ is the best filter available anywhere in Atlantis.
c) A store in one town sold filters from both companies. People who used both like *Hydroclean*™.
d) Measurements from a group further downstream along the Taiga says that *Hydroclean*™ filters made their drinking water 50% cleaner.
e) No, none of this evidence is helpful.

Water Filter Report Feedback.

"This is a difficult problem and I want to give you advice before you decide to leave this meeting.
Remember:
Deciding what evidence will be useful depends on the question you are asking. Some evidence is only good for answering certain questions. For now, there is only one question: which filter cleans water better? Therefore it is necessary to compare the filters. Do any of the choices use scientific evidence to compare the two filters?
You can revise your decision or explanation using the other computer in this meeting room. Its the computer in the corner.

When you finish, come talk to me at the front of the tunnel for your second report."

Bluegill Stream Report.



"Bluegill Stream continues to be an important river in Atlantis. Four towns sit on its shores. Upstream cities like Acadia (A) and downstream towns like Dalton(D) are all concerned about the chemicals used in Boma Town (B). Industries in Boma Town use chemicals to keep machines from overheating. The companies understand that some of their chemicals might pollute the soil and underground water. They plan to respond to this concern. The council received this summary of the Boma Town plan:

Boma Town engineers plan to use water from nearby Bluegill Stream instead of chemicals to cool their equipment. Pipes filled with cool stream water lower the temperature of the equipment. This process would use a lot of water but absolutely no chemicals. The pipes also keep the water from getting dirty. Therefore the heated water can be returned to the stream.

The council must advise the communities along Bluegill Stream soon. Is this a solution?"

a) This is a good solution for the industrial companies, and for the people downstream.
b) This is a good solution for the industrial companies, but not for the people downstream.
c) This is a good solution for the industrial companies, but not for the people upstream.
d) This is not a good solution for anyone; all communities will be harmed.
e) None of the above.

Bluegill Stream Report Feedback.

"Thanks! But before you leave the meeting room, think about this:
Have you ever noticed how trying to solve one problem can actually cause other things to go wrong? There really are many ways to solve the same problem. The reason there can be many solutions is because problems can have many parts. More and more, I believe it is important to always consider if a solution actually causes more problems. You know that chemicals can change water quality. Can temperature change water quality too?
If you are unsure about your decision or explanation, you can still make changes. Do you see the laptop in the corner of the room? Use that laptop to submit a NEW decision or a new explanation to the Council. When you finish, come back to the front of the tunnel before you leave the cave. Thanks!"

Appendix D

Formative Assessment Condition Quizzes and Feedback

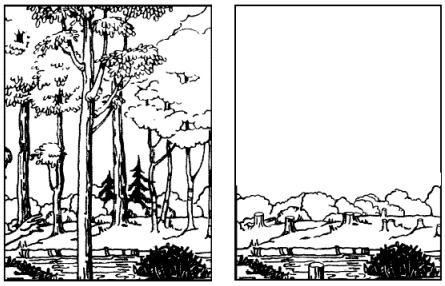
Mission 2 Quiz.

Mission 2 Quiz

Complete this quiz by yourself. Read each question carefully and respond in the space provided.

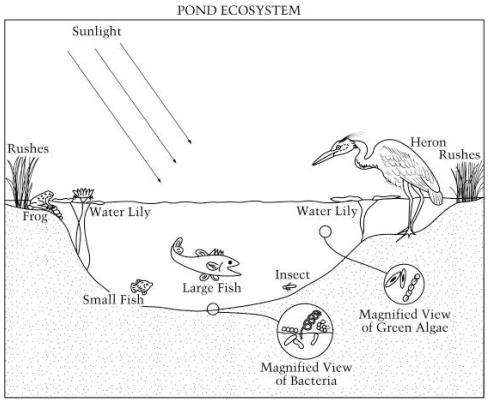
1. Many farmers apply chemical fertilizers to their soil to help plants grow or produce more. Which of the following is a negative impact that fertilizers have on human living conditions?

- **a.** The fertilizers pass into groundwater and pollute people's drinking water.
- **b.** The fertilizers dry out the soil and make it more vulnerable to wind erosion.
- **c.** The fertilizers damage the ozone layer that protects the earth from harmful radiation.
- **d.** The fertilizers can make the crops grow too much.



2. Using the images above, describe one *positive* thing that might result from cutting down the trees.

3. Using the images above, describe one *negative* thing that might result from cutting down the trees.



4. Use the diagram of a Pond Ecosystem above to answer the following two questions:

a. If a rainstorm washed some fertilizer from a nearby field into the pond, what would happen to the algae in the pond system after one month?

b. Why do you think the fertilizer would affect the algae this way?

5. On slopes along the edges of rivers, people often grow plants to prevent the soil from being eroded. Describe two ways that these plants keep the soil from eroding.

Mission 2 Feedback.

1. Deciding what evidence will be useful depends on the question you are asking. Some evidence is only good for answering certain questions. In this problem, there is only one question: which plant food helps plants the most? Therefore it is necessary to compare the plant foods. Do any of the choices use scientific evidence to compare the two plant foods?

3. Have you ever noticed how trying to solve one problem can actually cause other things to go wrong? There really are many ways to solve the same problem. The reason there can be many solutions is because problems can have many parts. More and more, it is important to always consider if a solution actually causes more problems. You know that human activities can change water quality. Can several cities together change water quality too?

Mission 3 Quiz.

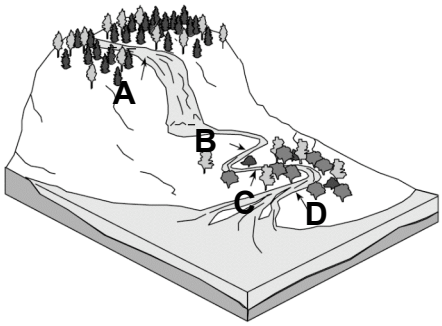
Mission 3 Quiz

1. Pat has two kinds of plant food, "Quickgrow" and "Supergrow." What would be the best way for Pat to find out which plant food helps a particular type of houseplant grow the most?

- **a.** Put some Quickgrow on a plant in the living room, put some Supergrow on a plant of the same type in the bedroom, and see which one grows the most.
- **b.** Find out how much each kind of plant food costs, because the more expensive kind is probably better for growing plants.
- **c.** Put some Quickgrow on a few plants, put the same amount of Supergrow on a few other plants of the same type, put all the plants in the same place, and see which group of plants grows the most.
- **d.** Look at the advertisements for Quickgrow, look at the advertisements for Supergrow, and see which one says it helps plants grow the most.

2. Explain why your choice above was the best way.

3. Suppose there are four cities along the river shown in the drawing at Points A, B, C, and D. All four cities get drinking water from the river and dump waste (sewage) into the river.



- **a.** How does the purity of the water change from Point A to Point D?

- **b.** Why does it change?

Mission 3 Feedback.

1. Deciding what evidence will be useful depends on the question you are asking. Some evidence is only good for answering certain questions. In this problem, there is only one question: which plant food helps plants the most? Therefore it is necessary to compare the plant foods. Do any of the choices use scientific evidence to compare the two plant foods?

3. Have you ever noticed how trying to solve one problem can actually cause other things to go wrong? There really are many ways to solve the same problem. The reason there can be many solutions is because problems can have many parts. More and more, it is important to always consider if a solution actually causes more problems. You know that human activities can change water quality. Can several cities together change water quality too?

Appendix E

Dates, Topics, and Duration of Site Visits for Each Study

TABLE E1

Timeline for 4th Grade Liminal Transition Enactment

Date	*Purpose*	*Duration*
11-16-2006	Logistics meeting with Becky	20 minutes
11-16-2006	Classroom observation – social studies	30 minutes
11-29-2006	Classroom observation – science	50 minutes
12-01-2006	Classroom observation – science	60 minutes
12-04-2006	Classroom observation – science	45 minutes
12-06-2006	Classroom observation – science	45 minutes
12-11-2006	Classroom observation – science	25 minutes
12-15-2006	Classroom observation – science	40 minutes
01-08-2007	Pre-testing	45 minutes
01-09-2007		45 minutes
01-10-2007	Classroom observation and technical support	50 minutes
01-11-2007		50 minutes
01-12-2007		50 minutes
01-16-2007		50 minutes
01-17-2007		50 minutes
01-18-2007		50 minutes
01-19-2007		50 minutes
01-22-2007		50 minutes
01-23-2007		50 minutes
01-24-2007		50 minutes
01-26-2007		50 minutes
01-29-2007		50 minutes
01-30-2007		50 minutes
02-02-2007		50 minutes
02-08-2007	Post-testing	45 minutes
02-09-2007		45 minutes
02-12-2007	Informal discussion with students	30 minutes

TABLE E2

Timeline for 6th Grade Liminal Transition Enactment

Date	*Purpose*	*Duration*
12-19-2006	Logistics meeting with Jack	20 minutes
01-26-2007	Classroom observation – science	50 minutes
01-29-2007	Classroom observation – science	50 minutes
02-01-2007	Pre-testing	90 minutes
02-05-2007	Classroom observation and technical support	50 minutes
02-06-2007		50 minutes
02-08-2007		50 minutes
02-09-2007		50 minutes
02-12-2007		50 minutes
02-15-2007		50 minutes
02-16-2007		50 minutes
02-19-2007		50 minutes
02-20-2007		50 minutes
02-22-2007		50 minutes
02-23-2007		50 minutes
02-26-2007		50 minutes
02-27-2007		50 minutes
03-01-2007		50 minutes
03-06-2007	Post-testing	90 minutes

Appendix F

Themes, Categories, and Their Descriptions for Chat Logs and Email Logs

TABLE F1

Themes in Chat Logs

Theme	*Description*
Collaborative story telling	Creating stories and alternative NPC dialogue in QA 3D space
Coordinated exploration	Finding a friend at A when you're at B for collaboration (e.g., finding NPCs) or play (e.g. hide-n-seek)
Logistics	Getting from A to B, time travel
Benchmarking	Communicating Mission progress
QA norms	Reiterating rules and the consequences of breaking them
Greetings	Salutations typically when students were not in the same room
Help-seeking	Questions about doing or finding things
Trading	Exchanging objects found in QA (e.g., gold)
Interaction	Responding to another's question, engaging in dialogue

TABLE F2

Categories from Email Logs

Category	*Description*
Non-curricular topics	Comments and inquiry of a personal or social nature students in the class and in the school
Announcements	Sharing insights with other students
Help-seeking	Questions about doing or finding things
Benchmarking	Communicating Mission progress
Coordinated exploration	Finding a friend at A when you're at B for collaboration (e.g., finding NPCs) or play (e.g. hide-n-seek)
Interaction	Responding to another's questions, engaging in dialogue

Appendix G

Sample Content Log Entries (Email and Chat)

No. Description

1. Cathy repeatedly CHATs that QA hates her and Frank telegrams to say that it does not.
2. Later in the period Cathy suggests that QA begins to like her again.
3. Will uses telegrams as memo at the end of the class period (12:15)
4. James a P4 or P5 student sick-at-home for the day enters the space, talks to several students, and appears to do some of his mission work (Taiga, 11:30)
5. Kate helps Janice find post 4 (11:53)
6. Frank helps Janice use the lab machine (12:06)

[S3, chat, 02-19-2007]

Appendix H

Analytic Categories for First Three Student Submission (Quest2, 2.5A and 2.5B)

TABLE H1

Coding for Quest 2 (Mission 2)

Dimension	*Focus*	*Excerpted Example from Student Submissions*
Water quality interpretations	Using Indicator Data (incorporate evidence from water analyses)	At site A the nitrates, phosphates, and temperature are too high [Gabriella, Quest 2, 02/22/07]
		At site A there is dead algae in the water and that all added up is really bad for fish. [Jose, Quest 2, 02/26/07]
	Relating to Taiga Activities (relate evidence to human activities in Taiga)	The reason the phosphates and nitrates are high is because the fertilizer carries large amounts of them. [Ron, Quest 2, 02/19/07]
		Activities that cause this are when the cow manure flows into the river and when loggers put logs in the river and sediments come out of that [Anthony, Quest 2, 02/27/07]
Systemic relations	Partial description (considers one upstream site only)	The logging might be changing this data because it can cause debris and mud and dirt to go into the water. The mud can cause a higher turbidity, which will make the fish to die. Also, the logs float downstream and they don't make a wide enough space and will raise the turbidity. [Alyssa, Quest 2, 02/15/07]
	Surface detail (addresses collective accumulation from upstream sites)	Site C [is] bad because of [indicators] being bad up higher on the river [where the other sites] had bad spots and it flowed down. [Becka, Quest 2, 02/23/07]
	Deep detail (distinguishes accumulation in terms of different sites and indicators)	I definitely know that the cause of the fish dying is coming from up-stream; because all of the problems of the water at site C are a cause of problems at site A and site B. The pH is fine at all sites. The amount of dissolved oxygen is low at site B, so it is low at site C. […] Since the turbidity is high at site B, the turbidity is still high at site C. [Jenny, Quest 2, 02/19/07]

TABLE H2

Coding for Sorting Out Diagrams Quest (Mission 2.5)

Description of Scientific Process	*Excerpted Example from Student Submissions*
Complete (describes complete process)	the heat from the sun warms the soil. The soil then warms the water. The water being warmer makes the Dissolved Oxygen go down and that is stressful on the fish so the fish end up dying. [Gabriella, SoD, 02/20/07]
Incomplete (describes process but omits key aspects)	the loggers are floating logs which puts sediments in the water, and the soil absorbs heat, heating up the water. That causes the organisms in the water to die. [Will, SoD, 02/22/07]
Misinterpreted (critical error in process)	the loggers drop logs in the river and that puts sediments in the river which makes it really hard to see which kills fish [Anthony, SoD, 02/20/07]
Implicit (aspects of process indicated but not connected)	there is a clear-cut in that space; maybe silt in water: cloudy; logs floating in river to get to Logging Mill; fewer vertebrates in that area than upstream. This diagram is important because it shows that soil from the logs is hurting the fish. [Sarah, SoD, 02/26/07]
Omitted (no processes discussed)	all of the diagrams it shows that fish die in the water [but at] different points in the water. [Becka, SoD, 02/20/07]
Denied (no process observed)	The scientists' were trying to show that what are causing less fish in Taiga. I don't think the diagram is important because it doesn't explain very much. [Aisha, SoD, 02/20/07]

TABLE H3

Coding for Mulu Proposal Quest (Mission 2.5)

Dimension	*Focus*	*Excerpted Example from Student Submissions*
Problems	Scientific (identifying ecological issues)	the more cattle the more manure, and the more plants [in the river], the more problems with the river. [Gary, Mulu Proposal, 02/16/07]
		They said that the additional land will help them grow more crops. The more crops they get the more fertilizer they will use. The fertilizer will run off into the water and make the water have a higher amount of cloudiness. The cloudiness causes even more fish to die. Also the sediments from the soil will wash into the stream. The sediments will get into the fish's gills and kill them. Also the more farming will cause erosion. The erosion can make it harder for the fish to breathe. It also makes the water very cloudy. [Casey, Mulu Proposal, 02/19/07]
	Social (identifying disparity or unfairness)	if they get that much land the loggers will want to take it over for logging. [John, Mulu Proposal, 02/26/07]
		when you look closer you realize that that is 100 less acres that the loggers have. The Loggers pay a huge fee to the park to log the area. […] Instead of depriving one of the groups of their income or land, I would suggest a compromise. [Carson, Mulu Proposal, 02/22/07]
Solutions	Limitations (qualifying approval of the proposal for scientific or social reasons)	use the land they own as efficiently as possible by not allowing cows so close to water and storing most manure in shed then sell it for more money. [Dan, Mulu Proposal, 02/16/07]
		The Mulu should be able to buy 50 acres. This should be enough for them to farm and keep their economy up. [Carson, Mulu Proposal, 02/22/07]
	Relocation (redefining proposal)	if they move their field away from the river then it would not kill more fish in the water [Connie, Mulu Proposal, 02/16/07]

Appendix I

Example of Sequenced Student Submissions with Codes

Quest 3	say that ranger Bartle should make everyone change something to their comapany. For an example the loggers should not cut down as many trees and they should replace the trees they cut down. The k-fly should replace all the fish that they kill in the contest. The mulu people should stopp suing fertlilizer because it causes the water to become cloudy and that is bad for the fish.
Mission 3.5 Textbox Dialogue: Water Filter	E None of the explanations are helpful because none of them provide scientific information. All of them just site opinions.
Mission 3.5 Textbox Dialogue: Bluegill Stream	D I think it is a good decision for everyone, except it when they dump the hot water in the river it might cause some harm. Other than that it's a pretty good decision.
Quest 4	Ranger Bartle did a lot to save the fish population. He figured out that it's everyone's fault for the causing of the fish problem, and that everyone contributed. He made all of the companies give up something to make the fish not die as much. I know that Ranger Bartle's solution worked because now there are a lot more fish. All the people are a lot happier and are not blaming the cause on everyone else. First, let's talk about the Mulu people. They gave up not using so much fertilizer. This worked because the water isn't as foggy and cloudy. The K-fly fishing had to replace the fish they killed in the tournament. This worked because now whatever money they earned in the contest they can use that money to replace the fish. The logging company had to give up leaving more trees between the river and forest because the sediments from cutting down the trees would run into the river causing a high DO. They've also had to replace whatever trees they've cut down.

Key:
Target Standard 3: Interconnectedness
Target Standard 2: Problem & Solution
Target Standard 1: Evidence

Appendix J

Study and Condition Means, Standard Deviations, and Effect Sizes

	Mean		Standard deviation		
Assessment type and level	Pre	Post	Pre	Post	Cohen's d
Fourth grade liminal transitions					
Curriculum-oriented, Proximal-level Performance Assessment	3.9	11.9	2.8	4.8	2.04
Curriculum-oriented, Proximal-level Multiple Choice	10.3	13.1	3.4	2.7	0.91
Standards-oriented, Distal-level Multiple Choice	10.1	12.7	4.5	5.1	0.54
Sixth grade liminal transitions condition					
Curriculum-oriented, Proximal-level Performance Assessment	7.4	12.3	3.3	4.5	1.24
Curriculum-oriented, Proximal-level Multiple Choice	11.3	13.0	3.3	3.9	0.47
Standards-oriented, Distal-level Multiple Choice	9.6	12.4	4.7	4.8	0.59
Sixth grade formative assessment condition					
Curriculum-oriented, Proximal-level Performance Assessment	7.5	13.0	3.6	6.3	1.07
Curriculum-oriented, Proximal-level Multiple Choice	10.4	11.4	2.8	4.3	0.28
Standards-oriented, Distal-level Multiple Choice	9.5	11.3	4.7	4.4	0.40

STEVEN J. ZUIKER

EDUCATION

Institution and Location	Degree	Year	Field
Indiana University - Bloomington, IN	PhD	2007	Learning Sciences
University of Georgia - Athens, GA	MA	2005	Educational Psychology
University of Illinois - Urbana-Champaign, IL	BS	1997	Psychology

PEER REVIEWED ARTICLES

Barab, S. A., Zuiker, S. J., Warren, S., Hickey, D. T., Ingram-Goble, A., Kwon, E. J., Herring, S., & Kouper, I. (in press). Embodied curriculum: Relating formalisms to contexts. *Science Education.*

Anderson, K., Zuiker, S. J., Taasoobshirazi, G., & Hickey, D. T. (in press). Classroom discourse as a tool to enhance formative assessment and practice in science. *International Journal of Science Education*.

Barab, S. A., Sadler, T., Heiselt, C., Hickey, D. T., & Zuiker, S. J. (2007). Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology, 16,* (1)*,* 59-82.

Taasoobshirazi, G., Zuiker, S. J., Anderson, K., & Hickey, D. T. (2006). Enhancing inquiry, understanding, and achievement in an astronomy multimedia learning environment. *Journal of Science Education and Technology, 15,* (5-6), 383-395.

Hickey, D. T., Zuiker, S. J., Taasoobshirazi, G., Schafer, N. J., & Michael, M. A. (2006). Balancing formative and summative assessment to attain systemic validity: Three is the magic number. *Studies in Educational Evaluation*, *32,* (3*)*, 180-201.

Hickey, D. T. & Zuiker, S. J. (2005). Engaged participation: A sociocultural model of motivation with implications for educational assessment. *Educational Assessment*, *10,* (3), 277–305.

Hickey, D. T. & Zuiker, S. J. (2003). A new perspective for evaluating innovative science learning environments. *Science Education, 87,* (2), 539-563.

BOOK REVIEWS

Roulston, K., & Zuiker, S. J. (2004). What's to look at in ethnomethodology's program? *Linguistics and Education*, *15*(3), 311-314.

MANUSCRIPTS

Barab, S. A., Scott, B., Ingram-Goble, A., Goldstone, R., Zuiker, S. J., & Warren, S. (in review). Embodiment as a curricular scaffold for transferable understanding. *Journal of Research in Science Teaching*.

INVITED PRESENTATIONS

Zuiker, S. J. (2007, April). The publishing process: How to successfully publish as graduate students and junior faculty members. Graduate Student Council invited fireside chat at the annual convention of the American Educational Research Association, Chicago, IL.

Hickey, D. T., Zuiker, S. J., & Anderson, K. A. (2007, September). Situative alignment of formative and summative assessment functions to maximize engagement and learning. Invited presentation at the biennial conference of the European Association for Research on Learning and Instruction. Budapest, Hungary.

CONFERENCE PAPERS

Zuiker, S. J., Barab, S., & Hickey, D. T. (2007, April). *Extending situativity: Liminal episodes in embodied experiences*. Paper presented at the annual convention of the American Educational Research Association, Chicago, IL.

Zuiker, S. J., Barab, S., Warren, S., Hickey, D. T., Aricci, A., Ingram-Goble, A., Kwon, E. J., Herring, S., & Kouper, I. (2007, April). *Developing a theory of formalisms: Socioscientific inquiry for schools*. Paper presented at the annual convention of the American Educational Research Association, Chicago, IL.

Zuiker, S. J., Kwon, E. J. & Hickey, D. T. (2006, April). *Assessment as formative design—and vice versa*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Scott, B., Barab, S., Ingram-Goble, A., Goldstone, R., Zuiker, S. J., & Warren, S. (2007, April). Embodiment as a curricular scaffold for transferable understanding. Paper presented at the annual convention of the American Educational Research Association, Chicago, IL.

Anderson, K., Zuiker, S. J., Taasoobshirazi, G., Horne, M., Cross, D., Hendricks, S., & Hickey, D. T. (2005, April). *Discourse, understanding, and achievement: design research methods for maximizing and documenting learning in multi-media science environments*. Presentation at the bi-annual Computer-Assisted Learning conference, Bristol, England.

Hickey, D. T., Zuiker, S. J., & McGee, S. (2004, April). *Defining levels and types of knowledge in educational design experimentation.* Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Hickey, D. T., & Zuiker, S. J. (2004, April). *Design experimentation with multiple levels of assessment and multiple types of outcomes.* Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Schafer, N. J., Hickey, D. T., Zuiker, S. J., Kruger, A. C., & Russell, H. A. (2003, April). *Using video feedback to facilitate classroom assessment conversation.* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Hickey, D. T., Kruger, A. C., Fredrick, L. D., Schafer, N. J., Russell, H. A., Bable, B., Hand, B., Micheal, M., & Zuiker, S. J. (2003, April). *Design experimentation using multiple perspectives.* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

CONFERENCE PRESENTATIONS

Zuiker, S. J. (2006, June). *A multi-level assessment strategy: (Dis)continuity in making learning visible differently*. Poster presented at the bi-annual International Conference of the Learning Sciences, Bloomington, IN.

Zuiker, S. J. (2006, April). *Apprenticeship in "the game": Learning to publish before you perish*. Presentation during Publications Committee's Open Meeting at the annual meeting of the American Educational Research Association, San Francisco, CA.

Zuiker, S. J., Hickey, D. T., Kwon, E. J., Chapman, R., & Barab, S. A. (2005, August). *Assessing student learning in, around, and for a multi-user virtual environment*. Presentation at the bi-annual conference of the European Association for Research on Learning and Instruction, Nicosia, Cyprus.

Zuiker, S. J. (2005, May). *Opening up practice: A micro-analysis of formative assessment within the GenScope assessment project*. Paper presented at The First International Congress of Qualitative Research, Champaign-Urbana, IL.

Zuiker, S. J., Hickey, D. T., Kwon, E. J., & Barab, S. A. (2005, April). *Framing Quest Atlantis: A multi-level/mutli-type assessment framework for learning and assessment*. Presentation at the bi-annual Computer Assisted Learning conference, Bristol, England.

Zuiker, S. J., & Hickey, D. T. (2004, April). *Identities for knowing: Analysis of discourse and transfer of learning during collaborative formative feedback activities*. Poster presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Zuiker, S. J. (2004, January). *The influence of context and identity in a formative feedback science activity*. Poster presented at the 17th Annual Conference on Interdisciplinary Qualitative Studies, Athens, GA.

Zuiker, S. J. (2002, February). *Sociocultural perspective on motivation in Tanzanian math classes.* Presentation at the annual meeting of the Comparative and International Education Society, Orlando, FL.

Anderson, K., Zuiker, S. J., Hickey, D. T., & Taasoobshirazi, G. (2005, April). *Discourse analysis for enhancing the formative value of classroom assessment practices in science*. Poster presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Hickey, D. T., Zuiker, S. J., & McGee, S. (2004, June). *A multi-level/multi-type model for design-based alignment of instruction, assessment, and testing.* Poster presented at the bi-annual International Conference of the Learning Sciences, Los Angeles, CA.

Schafer, N., Kruger, A., Russell, H. A., Michael, M., & Zuiker, S. J. (2004, April). *Coaching and video feedback for enhancing classroom assessment conversation and learning.* Poster presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Hickey, D. T., Zuiker, S. J., Taasoobshirazi, G., Schafer, N. J., & Michael, M. A. (2004, June). *Balancing formative and summative assessment to attain system validity: Three is the magic number*. Paper presented at the second EARLI SIG Assessment Symposium, Bergen, Norway.

Michael, M. A., Hickey, D. T., & Zuiker, S. J. (2004, June). *The role of motivation in systemically valid assessment*. Paper presented at the second EARLI SIG Assessment Symposium, Bergen, Norway.

Kruger, A., Schafer, N., Russell, H. A., Zuiker, S. J., & Michael, M. (2004, April). *A comparison of four different ways of coding engagement in videos of classroom activity*. Poster presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Hickey, D. T., & Zuiker, S. J. (2004, April). *Curricular overview and learning outcomes in the GenScope Assessment Project*. Poster presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Michael, M. A., Zuiker, S. J., & Hickey, D. T., (2003, April). *Motivating students to engage in meaningful assessment conversations: Effects of extrinsic recognition on learning and motivation.* Poster presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Michael, M. A., Zuiker, S. J., & Hickey, D. T., (2002, November). *Promoting learning and motivation in an intentional learning environment: Effects of extrinsic recognition and formative assessment practices*. Presentation at the annual meeting of the Georgia Educational Research Association, Savannah, GA.

REPORTS

Horne, M. A., Zuiker, S. J., & Hickey, D. T (2004). Design-Based Implementation & Evaluation: BioBLAST! 2003-2004 Implementation Report. Unpublished project report.

Stroman, A., Zuiker, S. J., & Hickey, D. T (2004). Design-Based Implementation & Evaluation: Exploring the Environment. 2003-2004 Implementation Report. Unpublished project report.

Taasoobshirazi, G., Zuiker, S. J., & Hickey, D. T (2004). Design-Based Implementation & Evaluation: Astronomy Village: Investigating the Universe. 2003-2004 Implementation Report. Unpublished project report.

CURRICULUM & EVALUATION

Zuiker, S. J., Jameson, E., Kwon, E. J. & Hickey, D. T. (2007). Quest Atlantis *Third Cycle Water Quality Unit Multi-level Assessments.* Unpublished assessments.

Zuiker, S. J., Kwon, E. J., & Hickey, D. T. (2006). Quest Atlantis *Second Cycle Water Quality Unit Multi-level Assessments.* Unpublished assessments.

Zuiker, S. J., Anderson, K., Cross, D., & Taasoobshirazi, G. (2005). Operation: Montserrat *Curriculum and Evaluation Assessments*. Unpublished assessments developed for Classroom of the Future at Wheeling Jesuit University, Wheeling, WV.

Zuiker, S. J., Chapman, R., Kwon, E. J., & Hickey, D. T. (2005). Quest Atlantis *First Cycle Water Quality Unit Assessments*. Unpublished assessments.

Horne, M. A., Taasoobshirazi, G., Zuiker, S. J., & Hickey, D. T (2004). BioBLAST! *for Georgia High Schools (revised)*. Unpublished curriculum and assessments (revised).

Horne, M. A., Zuiker, S. J., & Hickey, D. T (2004). BioBLAST! *for Georgia High Schools*. Unpublished curriculum and assessments.

Taasoobshirazi, G., Zuiker, S. J., & Hickey, D. T (2004). Astronomy Village: Investigating the Universe *for Georgia High Schools*. Unpublished curriculum and assessments.

Stroman, A., Zuiker, S. J., & Hickey, D. T (2004). Exploring the Environment *for Georgia High Schools*. Unpublished curriculum and assessments.

APPOINTMENTS

2006 - 2007 Associate Instructor, Department of Counseling and Educational Psychology, Indiana University.

2005 - 2007 Graduate Research Assistant, Center for Research on Learning and Technology, Indiana University.

Barab, S. A., Herring, S., Hickey, D., & Blanton, B. (2004). *Quest Atlantis: Advancing a socially-responsive, meta-game for learning*. Grant REC-0411846 from the National Science Foundation to Indiana University ($1,516,075)

2001 – 2005 Graduate Research Assistant, Learning and Performance Support Laboratory, University of Georgia.

Barab, S. A., Herring, S., Hickey, D., & Blanton, B. (2004). *Quest Atlantis: Advancing a socially-responsive, meta-game for learning*. Grant REC-0411846 from the National Science Foundation to Indiana University ($1,516,075)

Hickey, D. T. (2003). *Design-based implementation and evaluation of NASA CET multimedia science curriculum*. Subcontract from the NASA Center for Educational Technology to the University of Georgia ($290,604).

Hickey, D. T., Wallace, C., Hay, K., & Recesso, A. (2003). *Video-supported formative assessment of inquiry-oriented activity & instruction.* Grant from the UGA Professional Preparation of Educators Mini-Grant Program ($3,300) to the Learning and Performance Support Laboratory.

Hickey, D. T. (2001). *Assessment, motivation, & epistemological reconciliation in a technology-supported learning environment*. Grant REC-0196225 from the National Science Foundation, Division on Research, Evaluation, & Communication to the University of Georgia ($444,000).

1996 - 1997 Undergraduate Research Assistant, Clinical Psychophysiology Laboratory of Dr. Gregory Miller, Psychology Department, University of Illinois at Urbana-Champaign.

1995	Undergraduate Research Assistant, Cognitive Psychology Laboratory of Dr. Leonard Trejo, Psychology Department, University of Illinois at Urbana-Champaign.

SERVICE

2006 - 2007	Reviewer, *Journal of the Learning Sciences*
2004 – 2006	Student Editorial Advisory Board Member, *Educational Researcher: Research News & Comment,* Paul Schutz & Sonja Lanehart (Eds.)
2003 – 2006	Reviewer, Annual meeting of the American Education Research Association
2006	Session Organizer, Facilitator, & Reviewer, Bi-annual International Conference of the Learning Sciences
2006	Reviewer, Annual conference of the European Association for Research on Learning and Instruction - Junior Researchers
2004	Reviewer with Daniel T. Hickey, *Journal of the Learning Sciences*
2004	Reviewer with Peter Smagorinsky, *Research in the Teaching of English*
2004	Reviewer, *Educational Researcher: Research News & Comment*
2002 – 2004	Orientation Coordinator, Learning and Performance Support Laboratory, University of Georgia
2000	Elementary School Teacher, English as a Second Language, Esteban Figueroa Elementary School, Quetzaltenango, Guatemala.

TEACHING

Associate Instructor, Educational Psychology for Elementary Teachers, Indiana University, Bloomington, IN, 2006-2007.

High School Teacher, Math and Economics, Heritage High School, Spanish Harlem, NY, 2001.

High School Teacher, Math and Physics, Peace Corps, Tanzania, East Africa, 1998-2000.

AWARDS & HONORS

Reviewer of the Year, *Educational Researcher*, 2006
Student Leadership Team, *Carnegie Initiative for the Doctorate*, Department of Educational Psychology, University of Georgia
Departmental Fellowship, Department of Educational Psychology, The University of Georgia, 2001

PROFESSIONAL SOCIETIES

American Educational Research Association
European Association for Research on Learning and Instruction
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FOREIGN LANGUAGES

Spanish: read, write, and speak at an advanced level (high school and college coursework, 12 months living in Spain, Mexico, and Guatemala)
Swahili: read, write, and speak at an intermediate level (27 months in Tanzania)